AD-A053 596 KLING-LINDQUIST INC PHILADELPHIA PA F/G 13/13

INTERIM DESIGN CRITERIA, TECHNICAL GUIDELINES FOR ENERGY CONSER--ETC(U)

JAN 75 K N PATEL, H C SHANER, P J SARACENI N00025-74-C-0022

UNCLASSIFIED NL

1 OF 2

AD

A053596

AD A053596

INTERIM DESIGN CRITERIA

TECHNICAL GUIDELINES FOR ENERGY CONSERVATION IN EXISTING BUILDINGS

NAVAL FACILITIES ENGINEERING COMMAND
CONTRACT N00025-74-C-0022

JANUARY, 1975

PREPARED BY
KLING-LINDQUIST, INC., ENGINEERS
PHILADELPHIA, PA. 19107

unclassified

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (*and Subtitle*) 6 Interim Design Criteria, Technical Guidelines for Energy Conservation in Existing Buildings,	5. TYPE OF REPORT & PERIOD COVERED Int. Design Criteria
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Kling-Lindquist, New Inc. ~~Engineers~~ Philadelphia, Pa. ~~19107~~ 410674	8. CONTRACT OR GRANT NUMBER(s) 15 N00025-74-C-0022 new
9. PERFORMING ORGANIZATION NAME AND ADDRESS same as 8.	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 12 188p.
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Facilities Engineering Command 200 Stovall Street Code 043 Alexandria, Va. 22332	12. REPORT DATE 11 Jan[redacted]75
	13. NUMBER OF PAGES 186
14. MONITORING AGENCY NAME & ADDRESS (*if different from Controlling Office*) 10 Krishna N./Patel, Howard C./Shaner, Peter J./Saraceni, Boris S./Kudravetz Morris H./ Weinberg	15. SECURITY CLASS. (*of this report*) unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT

Unclas/unlimited

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

design criteria existing
energy conservation

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

This manual contains description, illustration and design criteria to be applied for energy conservation in buildings. Also included in the manual is the description and our recommendation of commercially available computer programs together with the sample printouts of computer analysis on an example building.

410 674 Gue

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

INTERIM DESIGN CRITERIA

"TECHNICAL GUIDELINES FOR ENERGY CONSERVATION IN EXISTING BUILDINGS"

PREPARED FOR:
THE NAVAL FACILITIES ENGINEERING COMMAND
NAVY CONTRACT N00025-74-C-0022

JANUARY, 1975

Prepared By:

KLING-LINDQUIST, INC.
ENGINEERS
Philadelphia, Pennsylvania 19107

Krishna N. Patel, P.E.
Howard C. Shaner, P.E.
Peter J. Saraceni, P.E.
Boris S. Kudravetz, P.E.
Morris H. Weinberg, P.E.
Kenneth M. Schotsch, E.I.T.
William E. Maronski

ABSTRACT

This submittal comprises final draft of design manual entitled "Technical Guidelines for Energy Conservation in Existing Buildings". The manual contains description, illustration and design criteria to be applied for energy conservation in buildings. Also included in the manual is the description and our recommendation of commercially available computer programs together with the sample printouts of computer analysis on an example building.

INTERIM DESIGN CRITERIA

"TECHNICAL GUIDELINES

FOR

ENERGY CONSERVATION

IN

EXISTING BUILDINGS

TABLE OF CONTENTS

Page

LIST OF FIGURES

Figure No.	Title	Page
3-24	Total Energy System Using Steam Boiler	3-61
3-25	Total Energy System Using Combustion Engine or Turbine	3-64
4-1A	Energy Using Control Without Deadband	4-3
4-1B	Energy Using Control With Deadband	4-4
4-1C	Composite Showing Energy Saving Using Deadband	4-5
4-2	Typical Centralized Control System Layout	4-7
4-3	Typical Multi-Building Control From a Single Control Console	4-8
4-4	Introduction of Wide Deadband Area Using 4°F Throttling Range For Heating and Cooling	4-11
5-1	The Energy System Analysis Series	5-3
5-2	Trace - Calculation Flow Chart	5-23
5-3	Example Building - Floor Plan	5-36
5-4	Constant Volume With Reheat and Perimeter Radiation	5-40
6-1	General Versus Task Lighting	6-2
6-2	Large Versus Small Area Lighting Advantages	6-6
6-3	Selective Switching Schemes	6-8
6-4	Light Output In Lumens Per Watt For Various Sources	6-11
6-5	Application of Power Factor Correction	6-13
6-6	Control of Peak Demand	6-14
6-7	277/480 Volt Distribution System	6-15

LIST OF TABLES

INTRODUCTION TO ENERGY MANAGEMENT

MANAGEMENT FOR CONSERVATION. The management of energy conservation for a given facility, like the management of any other function, requires planning, organizing, implementing and controlling the energy expenditure. For a facility not yet built, the planning involves the specification of certain guidelines, such as, the building envelope and ventilation criteria given in Chapter 1. It requires definition and evaluation of alternatives as outlined in the computer analysis discussion in Chapters 1 and 5 and the economic decisions discussed in Chapter 6. For every building project an energy balance diagram (Figure 2-2) should be prepared to graphically display the amount of internal energy available for recycling and to show the minimum amount of new energy required to maintain environmental conditions. This chart will guide the selection of alternative energy conservative systems. Once the alternative systems have been analyzed and one system selected, the computer model printout for that system should be preserved for later use by the responsible building operating personnel. In organizing or specifying, the building systems, the performance characteristics desired (especially coefficients of performance) must be clearly spelled out, and in implementing the design sufficient tests should be made of systems and their components to assure that, as installed, they meet the design requirements. On every project the building operator should be furnished with a complete set of as-built drawings and specifications and, also, with systems diagrams, operating and maintenance instructions, instructions for recording usage and demand of all energy sources. Actual usage of energy versus that estimated by the designer should be reported on a regular basis to assure that necessary corrections are made to controls for energy efficient operation. For each installation the officer-in-charge should designate an energy conservation officer to coordinate conservation efforts.

CHAPTER 1. UPDATING OF DESIGN PARAMETERS--VENTILATION, INFILTRATION, BUILDING ENVELOPE

1.1 PARAMETERS. In an existing building, the site (geographic location), orientation, occupancy schedule, controls, equipment sizes and selections are essentially fixed. However, the values of other basic parameters such as ventilation, infiltration, building envelope, "U" factor (walls, floor, glass, roof), and shading can be improved and should be evaluated as accurately as possible for energy and cost effective improvement. The evaluation shall consider bringing the "U" factor, ventilation and infiltration rates and other parameters to the levels specified for new construction.

1.2 VENTILATION AND INFILTRATION. Ventilation and infiltration rates in existing buildings are frequently higher than present standards require. Corrections can be accomplished by checking the outside air dampers, exhaust air from the building and air leakage into the building through damper blades, windows and door cracks, by minimizing the frequency of door and other openings, and controlling the stack or chimney effect. Block the present outside air damper or replace it with a smaller outside air damper adequately sized to furnish the desirable quantity of ventilation air. If 100 percent air usage is contemplated for economy/enthalpy control, install a separate damper for minimum outside air. This is essential to avoid losing control if one damper handles both minimum and maximum amount of air. The outside air damper shall function only when the building is occupied. A tight shut-off is required to minimize air leakage.

1.2.1 Reduction of Outdoor Air. Outside air requirements can be reduced considerably by installing an individual switch for toilet exhaust instead of tying it with lights. If a common fan is exhausting several areas, it should not operate at full capacity. This can be made variable volume by installing motorized dampers at each air inlet. The energy consumption required to meet heating and cooling loads due to ventilation can be further reduced by incorporating exhaust air heat recovery techniques as discussed in Chapter 3.

1.3 ENVELOPE. Thermal improvement goals for walls, ceiling, crawl spaces, etc. shall be those shown in Table 1-1. The heat transfer can be improved by added insulation, spraying with vermiculite, filling between studs with insulation, etc. For improvement of glass transmission and radiation, consider putting storm windows, storm doors, substituting single glass with glass blocks, insulating, double or triple glass, adding internal as well as external shading devices.

1.3.1 Economic Evaluations. Economic evaluations should be based on realistic estimates of energy usage. Records of oil, gas, electricity usage should be used for the existing situation. Estimates of energy savings due to added insulation, etc. may be based on a "degree-days" approach for air conditioned buildings of 10,000 square feet or less and for "heated only" buildings of 40,000 square feet or less. For larger buildings, energy estimates should be made by computer programs which simulate outdoor and indoor conditions.

1.3.2 Equipment Replacement. Another important energy conserving point is consideration of replacing or substituting components such as boilers, chillers, package air conditioning units, etc. When replacement is necessary, calculate heating and cooling loads based on present design parameters. Select equipment to meet this load instead of replacing it with the same size unit as before. Equipment selected shall be energy efficient as defined in Chapter 3.

1.4 TIGHTENING THE STRUCTURE. Leakage of dampers must be prevented by sealing the blades with a neoprene gasket seal on the leaf of the damper. The damper shall also remain closed during the warm up or pick up cycle. Some types of units, such as fan coil, or unit ventilators which have outside air openings without dampers, take in outside air when the unit is operating. This is an unnecessary ventilation load in the building at night when units operate to offset building heat losses. Install normally closed dampers in these openings and all other systems which operate in a similar fashion. Seal all air leaks in the building envelope. Caulk and seal all duct joints to ensure that ventilation air is carried to where it is needed. Minimize chimney effect

by blocking all unnecessary openings. The effect is more predominant in winter than in summer because of higher temperature and density differences. In winter air enters at a lower level and escapes at high level or at the roof. Tightening the building at the top moves the neutral point further down towards the lower level. Infiltration also can be reduced by weather-stripping, caulking, installing vestibules, revolving doors, etc. A vapor barrier prevents moisture migration and reduces infiltration. The barrier may be rigid sheets of reinforced plastics, aluminum or stainless steel or membranes of metal foil or coatings of resin or asphalt. Storm doors and windows are very effective in reducing infiltration.

1.5 VENTILATION AIR. Ventilation air may be outside air provided by forced ventilation or by infiltration or recirculated air purified by charcoal filters. During the heating season and during the cooling season if mechanical cooling is used, the ventilation air shall be limited to the design values contained in this section. Where power ventilation is provided, the total ventilation air quantity (including pressurization and infiltration) used for calculating heating and cooling loads shall be established as the greater of the total exhaust requirement or 0.125 CFM per square foot of net floor area, provided that ventilation air exclusive of infiltration is furnished at 5 CFM per person. Exhaust requirement values for toilets, kitchens, etc. shall be set at the minimum values recommended by ASHRAE Standard 62-73. Ventilation air quantity of 0.125 CFM per square foot will be adequate to meet general exhaust requirements and to pressurize the building to minimize infiltration. Five CFM/person will take care of heavily populated areas such as auditoriums, churches, theaters, arenas, convention halls, classrooms, cafeterias, conference rooms, meeting places, etc. Smoking should be prohibited in all assembly type areas.

1.5 1 Family Housing. Normally an outside air supply is not required in air conditioning family housing. Any exception is quarters for officers of flag rank for which an outside air supply shall be provided to meet the above requirements. The above ventilation rates are applicable for general use. ASHRAE's recommendation for ventilation shall be considered for special areas such as hospitals, laboratories, bakeries, restaurants, laundries, swimming pools, explosive manufacturing, contaminated areas such as smoking, toxic gases, etc., but in no case shall less than 5 CFM per person be allowed. For kitchen and dishwashing areas, the ventilation requirement for cooling shall be based on the internal load and air temperature rise of 15°F.

1.5.2 Variable Ventilation. For energy conservation provision for variable ventilation rates corres-

ponding to occupancy should be incorporated in the design of assembly type areas. All mechanical ventilation systems shall be equipped with readily accessible means for volume reduction and/or shut-off when ventilation is not required. Outside ventilation air intake in unoccupied buildings should be closed during early morning pick up cycle to achieve rapid acceleration to proper temperature (air cooling or heating), e.g., to bring an air-conditioned building down to temperature in the morning (0600 to 0730) before workers arrive.

1.5.3 INFILTRATION. Specifications should require that building windows and doors be designed and installed so that infiltration will be limited to 0.5 and 0.75 CFM per foot of crack for windows and doors respectively when tested at 1.567 pounds/square foot. Tests to confirm these rates of infiltration shall meet ASTM Standard E283-73 requirements. Infiltration must be considered as a room heat load and not as a system load, since it bypasses the air handling units and comes directly into the room. Caulking and weatherstripping reduces infiltration. Knowledge of prevailing wind will aid judgment in considering the crack length to be assumed in computing infiltration air quantity, but in no case will less than one-half the total crack be used.

1.5.4 VENTILATION FOR SPECIAL AREAS. Ventilation is required to provide adequate oxygen per person and to avoid build up of concentration of carbon dioxide in the space. The other purpose of ventilation is to remove body odors and where there is large volume per occupant less outside air is needed. Ventilation air requirements should be minimized to a value that will not unduly penalize the heating/cooling system energy requirements while providing a healthful environment.

1.5.5 THERMAL LOADS. The thermal load of ventilation air is directly proportional to the total quantity of the outside air and its magnitude is different for summer and winter conditions. The summer ventilation air contributes to sensible and latent heat loads, whereas winter ventilation load has a sensible component only. Any induced humidification provides the latent load in winter.

Summer ventilation load:

$$H_V \text{ (summer)} = 4.5 \times Q_V \times (h_o - h_i)$$

Winter ventilation load:

$$H_V \text{ (winter)} = 1.08 \times Q_V \times (t_i - t_o)$$

Winter humidification load:

$$W \text{ \#/HR} = \frac{Q_V \text{ (CFM)} \times 60 \text{ Min./Hr.} \times (G_i - G_o) \text{ (grains)}}{13.33 \text{ cu.ft./lb.} \times 7000 \text{ grains/lb.}}$$

$$= 0.00064 \times Q_V \times (G_i - G_o) \text{ \#/HR (Moisture)}$$

Where H_V = Ventilation air thermal load at outdoor design conditions (summer and winter) in BTUH

Q_V = Outside ventilation air, CFM at standard conditions (70°F, 0% R.H. and 29.92" Hg pressure)

Note: All air quantities mentioned in this manual correspond to Standard air conditions, and corresponding corrections must be applied for other conditions.

h_o = Enthalpy of outside air in BTU/lb. of air

h_i = Enthalpy of inside or room air in BTU/lb. of air

t_i = Room dry bulb temperature, °F

t_o = Outside winter design temperature, °F

W = Pounds per hour of moisture or steam required for humidification

G_i = Grains per pound of air at inside winter design conditions (at 70°F and 25% R.H. = 27 grains/lb.)

G_o = Grains per pound of air at outdoor winter design conditions (from "Engineering Weather Data")

1.5.6 EXAMPLE. Proper selection of ventilation air quantity reduces the first and the operating cost during both the heating and the cooling seasons. A 1000 CFM reduction in outdoor air (in the Philadelphia area) will represent a saving of about 2.7 tons in refrigeration equipment, 58,320 BTUH in heating equipment, and 14.1 pounds per hour of steam for humidification.

$$\text{Summer tons} = \frac{4.5 \times 1000 \times (39.57 - 32.4)}{12{,}000} = 2.70$$

Outside - 91 DB, 76 WB
Inside - 78 DB, 60% RH

Winter BTUH = 1.08 x 1000 x (70-16) = 58,320

Winter Humidification = 0.00064 x 1000 x (27-5) = 14.1

Reduction in air requirements for kitchen and industrial applications to achieve these savings may be obtained by the following considerations:

(1) Use of vented hoods directly over the heat producing equipment.

(2) Directly bringing the outside air into the area of hot spots or equipment to pick up the heat without causing draft conditions.

(3) Heat the outside air by recovering heat from hot waste gases through heat exchangers.

(4) Tighten up all unnecessary openings by installing well-fitted dampers for fireplaces. Fireplaces increase the heating requirements in a space so their use should be minimized.

(5) Use of double glazing and weatherstripping.

1.6 EXTERIOR ENVELOPE REQUIREMENTS - HEATING AND COOLING. The exterior envelope requirement shall apply to all buildings including special applications such as hospitals and laboratories. The intent of this requirement is to thermally optimize the exterior shell of a building, thus minimizing winter heat loss and summer heat gain. The selection of Heat Transmission Factor "U" (Btu/Hour/Square Foot/°F) is made by comparing heating and cooling criteria requirements and selecting the most restrictive value, i.e., the lower value of the two.

1.6.1 Heating Design Criteria. The heat transmission factors for walls, roof and floors shall not exceed the values shown in Table 1-1. (No interpolation for intermediate Degree Days values is permitted.) Glass selection for all buildings shall be based on economics, but in no case shall the overall heat transfer coefficient value (U_O) shown in Table 1-1 be exceeded when used in conjunction with the following equation:

Equation: $U_O A_O = U_W \times A_W + U_G \times A_G + U_D \times A_D$

Where U_O = the average thermal transmittance of the gross wall area and A_O = a unit area of gross wall.

U_W = thermal transmittance of opaque (net) wall area.

A_W = ratio of opaque (net) wall area to gross wall area.

U_G = thermal transmittance of window or glass.

A_G = ratio of window area to gross wall area.

U_D = thermal transmittance of door.

A_D = ratio of door area to gross wall area.

TABLE 1-1

Maximum[1] Walls, Roof, Floor and Overall Transmission Factor (U and U_O)

Degree-Days	Walls U_W	Roof U_R	Floor U_F	Family Quarters Gross U_O For Wall	All Other Buildings Gross U_O For Wall
0-2200	0.14	0.05	0.15	0.32	0.38
2201-4400	0.10	0.05	0.13	0.27	0.36
4401-6600	0.08	0.05	0.11	0.23	0.31
6601 and above	0.07	0.05	0.10	0.19	0.28

Degree-Days values from NAVFAC P-89 shall be used when available. Until the revised P-89 is available, use 1973 ASHRAE Systems Handbook or its latest issue. Value of U for wall, roof and floor shown in Table 1-1 shall not be greater than the following values corresponding to 97-1/2% winter ambient design temperatures: i.e., use the lowest of the two values obtained, one based on Degree-Day criteria and the other on winter ambient design criteria.

Temperature	Walls	Floor
-40°F to -10°F	.07	.05
- 9°F to +10°F	.10	.07
+11°F to +50°F	.15	.10

[1] Maximum U_O value will put a limitation on the allowable percentage of glass to gross wall area in a building. Insulation glass on the building will allow higher percentage of glass in comparison with single glass.

1.6.2 Perimeter Insulation. When heated spaces are adjacent to exterior walls in slab-on-grade construction, perimeter insulation shall be installed on the interior of foundation walls as follows: 1-inch thick when annual heating degree days of aggregate from 3,500 to 4,500, and 2 inches thick when the annual heating degree days are 4,500 and over. Installation of the insulation shall be in accordance with the ASHRAE Guide.

1.6.3 Condensation Control - Heating. The design of the building envelope shall provide protection against cold weather water-vapor condensation on or in roofs, attics, walls, windows, doors, and floors. For opaque areas of ceilings, roofs, floors, and walls containing dry thermal insulation, a continuous vapor barrier having a water vapor permeance not exceeding 0.5 perm (grains/hr ft^2 (in.-Hg) is required on the winter-time warm side of the insulation. Slab-on-grade floors shall have a vapor barrier with lapped joints under the slab not exceeding 0.1 perm. A vapor barrier not exceeding 0.1 perm shall be required to cover the ground area of a crawl space beneath floors. Ceiling,roof, floor, and wall constructions shall contain thermal breaks to prevent excessive heat transmission through framing members.

1.6.4 Cooling Design Criteria. Materials shall be specified so that wall (net area) and roof heat gain shall not exceed 2.0 Btuh per square foot at design conditions. All glass, except north glass, shall have a shading device (e.g., shades, venetian blinds, draperies, awnings, eyebrow reveals, or vertical/horizontal fins), and maximum instantaneous transmission and solar gain through glass shall not exceed 70 Btuh per square foot as an average for the entire building (i.e., block load figure). This average of maximum instantaneous solar and transmission factors includes shading factor. Thermal storage effect due to mass of building must be accounted for to produce properly sized system, capable of balancing the actual loads. For buildings that are cooled only the overall thermal transmittance U_O for the gross wall shall not exceed 0.32 for family quarters and 0.38 for all other buildings.

1.7 HEATING AND COOLING LOADS. These loads shall be calculated in accordance with one of the procedures specified in the 1972 or latest issue of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Handbook of Fundamentals.

1.7.1 Simplified Method for Small Buildings. For family quarters and other buildings with a gross floor area less than or equal to 10,000 square feet, if both heated and cooled or 40,000 square feet if heated only, the simplified and manual method as discussed in Part 1, General Cooling Load Calculations, Chapter 22, in the 1972 ASHRAE Handbook of Fundamentals, shall be used. Show design calculations, method, results, and heat balance chart (see Chapter 2). Annual energy requirements for residential type buildings,such as single family dwellings and family quarters, using Degree Day method for heating and Equivalent Full-load Hour method for cooling as discussed in Chapter 43 of 1973 ASHRAE Systems Handbook or its latest edition. For other smaller buildings annual energy requirements should be obtained by the "bin" or temperature frequency occurence method as discussed in Chapter 43, Page 43.13 of 1973 ASHRAE Systems Handbook or its latest edition. Bin system data at 5° interval must be obtained from NAVFAC P-89 "Engineering Weather Data" manual. Adequate credit must be taken for the heat reclaiming systems. Additional data on system incorporating heat pumps is given in Chapter 11 of 1973 ASHRAE Systems Handbook.

1.7.2 COMPUTER ANALYSIS. For buildings larger than 10,000 square feet, an extensive hourly dynamic analysis for load as well as energy calculating procedure shall be made using advanced computer techniques and hourly weather data prepared from the sources of NAVFAC P-89 or as obtained from The National Climatic Center of National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Environmental Data Service, Federal Building, Ashville, North Carolina 28801. Load and energy calculations shall be made using the design parameters as discussed in the earlier section on site, outdoor design conditions, indoor design conditions, ventilation, infiltration, solar screening; and ex-

terior envelope-walls, floor, glass and roof. The annual hourly energy analysis (8,760 hours) shall incorporate the effectiveness of energy conservation features and systems as discussed in Chapter 3. A computer program for dynamic analysis to simulate the operation of all the buildings through a full-year operating period shall be of sufficient detail to permit the evaluation of the effect of system design and operational characteristics (such as space temperature and humidity control, supply air flow and temperature, nature of fuel or energy source, outside air quantities, lighting and occupancy schedules) and mechanical plant characteristics (such as part-load profiles, sequencing and accessories) on annual energy usage. See Chapter 5 for more details. Manufacturer's data or comparable field test data shall be used, when available, in the simulation of all systems and equipment. The calculation procedure shall utilize simulation techniques similar to the current recommendations in accordance with ASHRAE Task Group publication entitled "Proposed Procedure for Simulating the Performance of Components and Systems for Energy Calculations." The energy consumption for heating and cooling are directly related to the actual weather conditions and also the systems selected. The purpose of this calculation procedure is to get overall savings in owning and operating costs due to more precise sizing of the equipment selected and careful control of heating and cooling system operation. The computer programs need minimum repetition and maximum utilization of the input data. Alternate designs for the same building can be obtained with very little effort by changing few design constants or type of systems and submitting to the program for a rerun. To allow the equipment selected to operate close to design capacity, no additional safety factors, above what are inherent in the ASHRAE method, shall be allowed.

CHAPTER 2. ENERGY CONSERVATION CHECK LIST

2.1 HEATING.

2.1.1 Check heating load against calculated load using degree days and heat loss. Use computer analysis for larger buildings greater than 10,000 sq.ft. for air conditioned building, and greater than 40,000 sq.ft. for heated only building.

2.1.2 Reduce or turn off heat in less critical and unoccupied areas. (warehouse, docks, etc.)

2.1.3 Control outdoor air to meet design requirements. Close ventilation dampers during unoccupied periods such as nights, weekends and holidays. Design for variable outdoor air.

2.1.4 Doors and windows should be in good repair and closed in winter. Fix all air leaks.

2.1.5 Check to find if any of the areas are overheated. Reduce heat in these areas. Do not open windows in winter to cool an area. Fix broken windows, etc.

2.1.6 Minimize building exhaust - third shift - weekends.

2.1.7 Distribution lines shall be insulated. Replace deteriorated insulation.

2.1.8 Check and fix any leaking distribution lines.

2.1.9 Close all unnecessary roof openings.

2.1.10 Steam System Supplement

2.1.10.1 Boilers.

(1) Keep record of boiler thermal efficiency.

(2) Consider use of flue gases for possible waste heat recovery.

(3) Keep accurate records of the cost of generating steam.

(4) Check the possibility to coal conversion or using plant waste or motor oil as fuel.

(5) Accurate check on delivered oil quantities.

(6) Determine if the boiler plant is really needed in summer. Could small boilers and water heaters be used and the power house shut down for the summer.

2.1.10.2 Condensate systems.

(1) Return all good condensate. Check condition of pumps.

(2) Insulate condensate lines.

(3) Maintain all equipment in good order - temperature controllers, leaky valves, float valves, steam traps, piping, etc. Establish a periodic maintenance program for the above equipment.

2.1.10.3 Perform flue gas analysis of boilers and other fuel burning equipment to optimize the efficiency of combustion, excess air required and heat loss to stack.

2.1.10.4 Make sure summer ventilation is off in heating season.

2.1.10.5 Check for any visible building openings which should be closed - such as stuck dampers or louvers on exhaust systems.

2.1.10.6 Shut off any heating mains accidentally left on.

2.2 COMPRESSED AIR.

2.2.1 Measure and repair leaks.

2.2.2 Turn off air at the stations when not in use.

2.2.3 Turn off air after cleaning operations.

2.2.4 Use conservation nozzles on air ejection applications.

2.2.5 Analyze all air using equipment to determine the lowest pressure at which the air compressors may be operated.

2.2.6 Study to determine if pressure blowers could replace some use of compressed air. Do not allow compressed air to be used to cool personnel.

2.3 WATER.

2.3.1 Control all welders, degreasers either automatically or manually to conserve water.

2.3.2 Repair leaks promptly.

2.3.3 Heat exchanger should be water controlled for economical use.

2.3.4 Recirculating systems should be used where possible.

2.4 ELECTRIC POWER.

2.4.1 Shut off lights where not needed at lunch and end of shift. Clean dirty fixtures to insure greater efficiency of lighting. Light off program should be intensified and expanded.

2.4.2 Remove lights in areas not needed - some stock rooms, aisles, etc.

2.4.3 Reduce parking lot lighting to minimum, yet maintain security and safety. Provide selective control for parking lot.

2.4.4 Reduce all decorative and advertising lighting.

2.4.5 Demand and power factor should be controlled.

2.4.6 Substitute smaller size motors where they are grossly oversized.

2.4.7 Maintain electric control properly to prevent overheating. Consider staging of controls.

2.4.8 Check motor actuating control operation to prevent any unnecessary motor operations.

2.4.9 Check what lights are left overnight. Justify this as well as weekend electric power usage.

2.4.10 Check to confirm that only the best power rate is being used.

2.4.11 Consider the possibility of deenergizing any transformers to save losses. Transformer heat exchange surfaces should be clean to reduce heating.

2.4.12 Shut off all equipment when not in use - at relief periods, lunch, end of shift, weekends, nights, holidays.

2.4.13 Consider installing fluorescent lamps in areas now lighted by incandescent lamps.

2.5 NATURAL GASES AND OTHER FOSSIL FUELS.

2.5.1 Use proper burner tips.

2.5.2 Maintain furnace controls and burners for best efficiency.

2.5.3 Provide adequate insulation to minimize losses.

2.5.4 Automatic controls must be installed and maintained to minimize waste.

2.5.5 Check accuracy of delivered gases for billing.

2.5.6 Make routine checks for leaks.

2.5.7 Maintain accurate usage record.

2.6 AIR CONDITIONING.

2.6.1 Control outside doors. Readjust outside air dampers to minimize outside air usage.

2.6.2 Consider using timers on package units at night or weekends to save utility cost.

2.6.3 Check thermostat setting during occupied and unoccupied hours.

2.6.4 Check the preventive maintenance program on all air filters and heat exchangers to assure maximum efficiency.

2.6.5 Study the plant heating and air conditioning systems to determine if they are of correct design.

2.6.6 Eliminate stratification of air in plant in winter. This will cool the ceiling and warm the floor.

2.6.7 Reduce the quantity of air exhausted from the building. Use local exhaust not general.

2.6.8 Where possible, use exhaust air to warm incoming air by mixing the air streams.

2.6.9 If exhaust air is contaminated, evaluate air cleaning devices to determine if the air could be cleaned and recirculated.

2.6.10 Study the possibility of utilizing the energy in contaminated air in production operations before it is exhausted.

2.6.11 If all other procedures are not applicable, determine which is the most suitable heat transfer device (heat recovery wheels, heat pipes, run a-round coils, etc.) to incorporate into the exhaust system.

2.6.12 Use some automatic device to control the volume of water and air used.

2.6.13 Do not operate cooling tower in winter - use heat in water to temper building or incoming air.

2.6.14 Consider using waste water in summer as roof sprays. This will cool the roof and reduce heat entering the plan t.

2.6.15 Use insulated storage for chilled water. This will reduce the size of refrigeration machine. At least one office building operates its compressors at

night only - computer areas. This could also be done for hot liquids.

2.6.16 Use spot heating or cooling of people when they are located far apart. Each should have control of the air direction and velocity over them.

2.6.17 Consider use of evaporative coolers in place of refrigeration cooling.

2.6.18 Check HVAC system balance for maximum efficiency - air, water.

2.6.19 Consider providing interlocks on heating and cooling equipment to prevent simultaneous operation of heating and cooling systems in adjacent or nearby zones.

2.7 BUILDING ENVELOPE

2.7.1 Check type and percentage of glass. Measure all infiltration leakage. Caulk or weatherstrip to minimize infiltration. Consider the economics of replacing building glass with double-glazed insulating glass.

2.7.2 Check wall, floor and roof construction and calculate heat transfer coefficient and thermal loads. Consider practicability and limitation of addition of insulation if these components are not adequately insulated.

2.7.3 Type of doors and infiltration quantity. Minimize this by storm doors, caulking and weatherstripping. Consider using insulating glass.

2.7.4 Block off any visible openings and cracks.

2.8 PROCESS AND MISCELLANEOUS ITEMS.

2.8.1 Shut off paint booth supply and exhaust fans when not in use.

2.8.2 Shut off parts washer when not in use, i.e., pumps, steam to tanks and exhaust fans. Keep covers on the tanks closed.

2.8.3 Shut off drying and curing ovens when not in use. Do not start too early before shift time.

2.8.4 Shut off inter-plant outside truck engines when not in use.

2.8.5 Analyze inter-plant truck runs, consolidate loads and eliminate trips.

2.8.6 Shut off fork truck engines when not in use.

2.8.7 Reduce water temperature in rest rooms.

2.8.8 Check all process exhaust systems to see that they are exhausting only the proper amount of air and at desired time only.

2.8.9 Shroud openings of furnaces, ovens, paint booths and washers so that the minimum amount of exhuast air will be required.

2.8.10 Use cold water detergent in washers whenever possible.

2.8.11 Where possible, combine operations and reduce the number of washers.

2.8.12 Plan weekend work so that the whole plant can be shut down on given weekends.

2.8.13 Reschedule operations wherever possible to second and third shift to get them off the 10:00 A.M. to 2:00 P.M. peak electrical demand period.

2.8.14 Study all solid waste to determine if it can be recycled, burned or composted.

2.8.15 Salvage all oil used in plant. It can either be reused by refining it or it can be burned in the boiler.

2.8.16 Use "low-volume - high velocity" exhaust systems where possible. These include ventilated welding guns, hoods for portable grinding equipment, local

traveling hoods for molten metal pouring, as well as a unique method of controlling mist from oil mist lubricators.

2.9 PROGRAM SCHEDULE. A successful program to implement the previously discussed items requires backing of top management and their regular weekly, bi-weekly or monthly auditing the results of conservation. Goals should be determined and records developed to show status of the program. Compare energy usage by each department. The sooner definite results can be shown the more enthusiasm will be generated and the faster the program will move forward.

CHAPTER 3. SYSTEMS AND RECOVERY TECHNIQUES

Section 1. CONVERSION, ADDITIONS OR MODIFICATIONS TO EXISTING HAVAC SYSTEMS TO IMPROVE ENERGY EFFICIENCY

3.1.1 CONSIDERATION FOR ENERGY CONSERVATION. Most of the effort expended to date on improving the energy efficiency or reducing the consumption of energy in existing buildings has been directed toward reducing existing loads. Reductions in air circulated, lighting loads, ventilation air quantities, and easing design conditions all can make some contribution. Other efforts have been to diminish outright waste from steam and water piping, overheating and overcooling, shortening operating hours, etc. The actual conversion or additions to an operating HVAC system to improve the efficiency of energy use will involve the expenditure of possibly large sums of money. Economic analysis of possible modifications should be run to justify expenditures. In some cases, particularly in the exchange of heat between large volumes of outside and exhaust air by means of wheels or coils, the economic gain in lowered fuel consumption immediately justifies the expense. In others the return on investment would extend over many years or possibly never prove profitable. From knowledge of past practices in design and our new understanding of how some of the energy consumed in buildings is wasted, we can consider some possibilities for change. The basic error now apparent which has led to the struggle to devise heat recovery methods is that in practically all HVAC designs we have been heating and cooling the building space at the same time. The internal cooling load whether being rejected by condensers, or by relief or "dump" fans is lost to outdoors. At the same time new energy is consumed to heat the exterior zones. If radiation at the walls is not properly controlled, surplus heat may be transferring to the interior air to further increase the refrigeration load. At the same time areas on reheat control are adding heat to the system at some locations to hold the temperature up.

(1) Radiation. The first possibility would be to see if the radiation system is properly controlled and zoned. Some systems are single circuit, fixed temperature, constant flow occasionally having convector cabinets with air dampers or radiators with shut-off valves. These are under random control and most likely to be overheating in some spaces. Each building face is exposed to a different heating condition. Therefore, ideally each should have its own circuit. This is not always done and the number of zones is reduced to two or three. Common combinations are east, south, and north and west together or if two zones, south with either west or east, and north with either west or east. Local prevailing winds, and particular winter characteristics leave the combinations for the engineer's judgment. An extensive south exposure should be separately zoned because of the intensity of winter solar incidence here. The water temperature can be scheduled with proper controls from ambient outdoor readings and include a reset device to adjust for solar effect. Other zones or combinations should also be on a preset water temperature reflecting outdoor conditions. How expensive modification of the zoning is will depend upon existing pipe circuits. Recirculating type piping arrangements with three-way valve control at each zone are required for separately controlled zone circuits. Much more efficient use of heating energy will be realized.

(2) Elimination of Reheat. Among the systems using terminal reheat, the dual air duct design offers the best possibility for conversion. This is traditionally a medium to high pressure delivery system and as such could be converted to a variable air volume system. Cold air is diffused at 55° to 58° in both systems. In design the cold air duct carries the full air quantity needed for cooling. Hot air connections must be removed from each control box and capped. Interlocking mixing damper rods removed and the cold air damper operated alone from the room stat. Air terminals used in newly designed variable air volume systems differ from the standard circular or square ceiling diffusers. Linear, modular slots and light troffer distribution are common. Early thoughts were that standard ceiling diffusers would "dump" at

reduced flow velocities. Opinion now is that the Cowanda effect is retained through a wide range of flow reduction and this will prevent "dumping" unless the diffuser was grossly oversized in the beginning. Before making the decision to replace all the diffusers it will be profitable to have one smoke tested under variable air volume flow. At the air apparatus, the fan must be provided with inlet vane dampers controlled by static pressure in the supply duct. As total flow reduces, vanes close, thus reducing fan horsepower.

(3) Reheat by Secondary Energy. Where terminal reheat is furnished by hot water booster coils, it appears at first glance all that is required is to switch the circulating pump from a prime interchanger to a hot condenser water source. This is only partly true. All of the coil surfaces were probably selected for 190° average water temperature. The output at 115° average temperature will be reduced. Each of the coils must be re-examined for its heating capability under the new average water temperature. This is not as bad as it sounds. Many booster heater systems are reset in summer to operate between 120° and 140° leaving the interchanger. With present recommendations to reduce the range of reheat and let the space drop two or three degrees on light load most of the installed coils will prove adequate. The places to look for trouble are top floors and ceilings below roof offsets where roof loads were added to the reheaters. Here, if the insulation is in the roof construction and space is available above the ceiling, a few pipe coils or light finned tube radiation will remove the need of high water temperatures on the booster coil altogether.

(4) Conversion of Low Pressure Ductwork. If consideration is being given to modify a low pressure, terminal reheat system to variable air volume use, the critical point is how well the ducts were originally constructed. Air leakage is the major concern and this varies with each installation. A little caulking and taping will make a well-made job perfectly adequate to withstand the 3 to 5 inch pressure of a variable volume system without undue leakage. It may

be impossible to tighten up a poorly constructed system. The self-contained air control devices need from 3/4" to 1-1/2" static pressure for proper operation and this will be in addition to the previous operating static pressure of the discharge duct. Much more extensive cutting and patching will be necessary above that for modifying a dual air duct system. Joints must be removed to insert air control valves, heaters removed, etc. Comments previously made regarding diffusers must be observed. An alternate method is to discontinue the use of all present outlets and use one of the several manufactured lines which combine air valve and diffuser. To increase total system pressure to this extent, a new fan with vane control is probably required. In any conversion to variable air volume using 55° to 58° diffusion air temperature, do not disregard the need for a minimum of 1" insulation on all supply air ductwork from fan to the most distant outlet. Temperature rise of the supply air may otherwise result in inability to maintain space conditions, particularly over the longest runs.

(5) Conversion of Refrigeration Equipment. There are a number of changes possible to operating plants to make use of condenser heat. The amount of heat now thrown away through cooling towers is tremendous. The first problem with standard existing machinery is in the low condensing temperatures used for efficient operation, 100° to 105° is a relatively low temperature for heating purposes. Centrifugal compressors designed for double bundle or high temperature condensing are high lift, industrial type discharging condenser water in the 120° to 130° range. Unless the plant is nearly obsolete or replacement for other reasons is due, it is not likely all present equipment will be discarded.

(a) Discontinue cooling tower, substitute a closed circuit cooler and connect to the building radiation system. Condenser water pump heads must be checked. Provide supplementary heat in circuit to raise water temperature out to radiation. Safety control is required on return to limit maximum return water temperature.

(b) If space is available, install a high lift heating machine in cascade with one existing centrifugal. Use resulting 130° to 140° water directly to radiation or reheaters.

(c) The use of condenser water at 105° directly to perimeter radiation is being designed in new construction. It requires approximately 2.9 times the air side surface in the radiation as it does for a standard 190° average water temperature selection. It is obvious that in existing systems with radiation sized for the higher temperatures, 105° water would be effective only in mild spring and fall weather. In adding supplementary heat to this water, the critical point is to avoid return water temperatures above 95°. It is important not to make the assumption that you can use 20°, 25°, or 30° drop in the water circuit to increase the heating effect of 105° water. The variables in the selection of the original radiation such as fin spacing, tube size and stack head all limit the extent of heat transfer. If part of the condenser water is diverted to reheat, this will further reduce the average return water. In any case, closed circuit coolers must be used to control the temperature of condenser water in excess of that effectively used. The use of 105° water becomes more effective in booster coils, fan coil units and induction units where forced flow of the air stream is present. Heat transfer is then a function of air and water velocities and air side surface.

Section 2. HEAT BALANCE

3.2.1 HEAT BALANCE ANALYSIS. In order to establish the maximum potential benefit of energy conservation, a heat balance analysis should be made of all major heat load contributors at the beginning of design. The analysis involves first, a calculation of building envelope heat gain or loss and the probable indoor heat contributors for all conditions of outside temperature. Secondly, the net heating/cooling requirement for the building as a whole is plotted graphically to permit visual evaluation of the heat balance components. The analysis should always include the six following internal heat contributing parameters:

(1) Exterior envelope conduction load of walls, glass, floor, and roof, i.e., heat loss in winter and heat gain in summer. This is a sensible load due to different ambient and space temperatures.

(2) Ventilation load is the outside air load brought through air handling systems and infiltration air. The infiltration air is air leakage in the building through walls, doors, glass, and roof due to wind pressure differential and due to the chimney or stack effect created by temperature differences. The ventilation load consists of both sensible and latent load components, the former being predominant in winter. The intent of using this load is to get the breakeven temperature which most of the time is in the vicinity of winter design temperature. For this reason,and for simplicity,only sensible load figures will be used for heat balance.

(3) Light and power load is due to luminaires and electrical machinery (typewriters, copying machines, calculators, etc.). For heat balance, light load (H_L) may be taken as 90 percent of installed capacity. This is because all lights may not be on at the same time and some fixtures may be in need of repair or replacement. For power load (H_p) use no less than 50 percent diversity on the installed capacity.

(4) Occupancy or people load is obtained by multiplying the number of people (occupancy for which the building is designed, less visitors) times sensible load/person. Only sensible load is to be used for the same reason mentioned earlier. Typical value of this depends upon the degree of activity and is, for standing, light work or walking slowly = 250 BTU/hour. Values for other activities may be obtained from the 1972 ASHRAE Handbook of Fundamentals, Table 29, page 416. For constructing a heat balance chart use 80 percent of the calculated occupancy load assuming all persons will not be present in the building at the same time.

(5) Equipment load includes energy of fans, pumps, computers, heat of compression and any other heat producing equipment. Heat of compression to be used only in the system incorporating double bundle or heat pumps. See Section 3.

(6) Solar load can be obtained from heat gain data (cooling load).

All the above values can be easily obtained from computer printouts where they are used for load calculations and energy analysis.

For small projects on which computer analysis is not used the values may be simply derived as follows:

A. $H_T = \Sigma\, UAdt$

B. $H_{VS} = 1.08 \times Q_V \times \Delta t$

C. Total light and power load: $H_{LP} = 0.90 \times H_L + 0.50 \times H_P$ BTUH, where H_L and H_P = kilowatts x 3413.

D. H_O = No. of people x sensible load/person x 0.80

E. $H_E = \dfrac{\text{Brakehorsepower (BHP)} \times \text{\% load} \times 2545}{\text{Efficiency (at corresponding load)}}$

Notations:

H_T - Conduction load at various ambient temperatures, BTUH

H_{TPW} - Peak winter conduction load, BTUH

T_W - Ambient winter design dry bulb temperature, degrees F.

T_I - Inside or room design dry bulb temperature, degrees F.

H_{VS} - Sensible ventilation load, BTUH

Q_V - Outside or ventilation air, CFM

H_{LP} - Diversified light and power load, BTUH

H_O - People sensible load, BTUH

H_E - Equipment load, BTUH

H_S - Solar heat gain, BTUH

The heat balance chart as well as monthly energy usage chart must be prepared for all buildings.

3.2.2 HEAT BALANCE DIAGRAM. A graphic representation of the calculated heat loads is plotted to give a simplified graphic overview of the heat contribution from all energy components and to establish the relative merits of balanced heat recovery at various outdoor temperatures. Figures 3-1A and 1B show individual major load components which are summarized in the composite heat balance illustrated in Figure 3-2. Breakeven temperature (T_{BE}) the temperature corresponding to the outdoor temperature at which the heat from the internal energy components balances with the heat losses in a building, with and without the sun, can be obtained from the graph. Breakeven temperature for most buildings falls in the vicinity of winter design temperatures. There is surplus heat in the interior spaces and heat is required along the exterior envelope to offset winter heat losses. It is possible to eliminate any external heat source for energy demands during occupied hours for a system designed to take full benefit of transfer of heat from surplus zones to where it is needed. Consideration of heat recovery techniques can

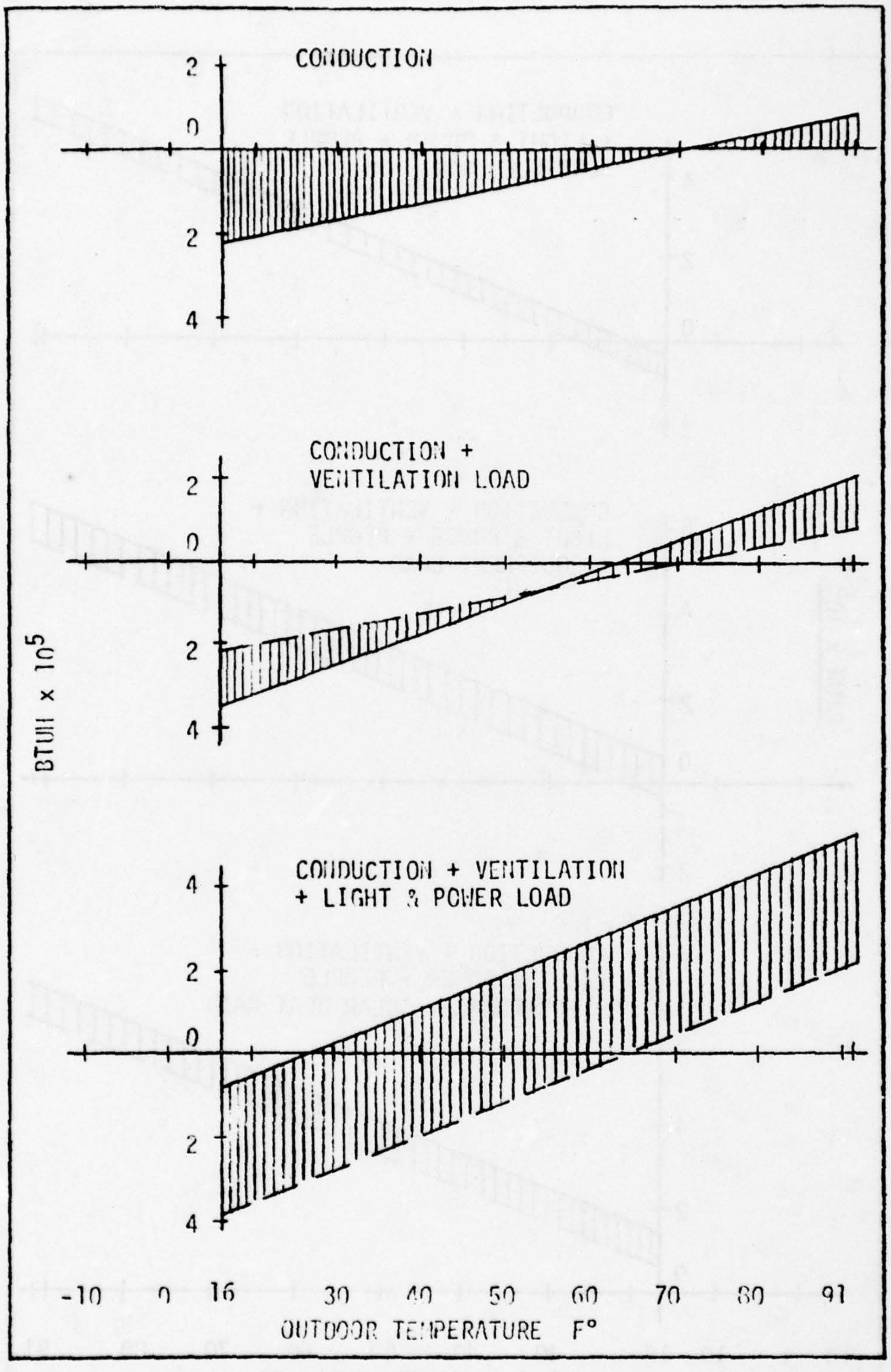


FIGURE 3-1A
MAJOR LOAD COMPONENTS

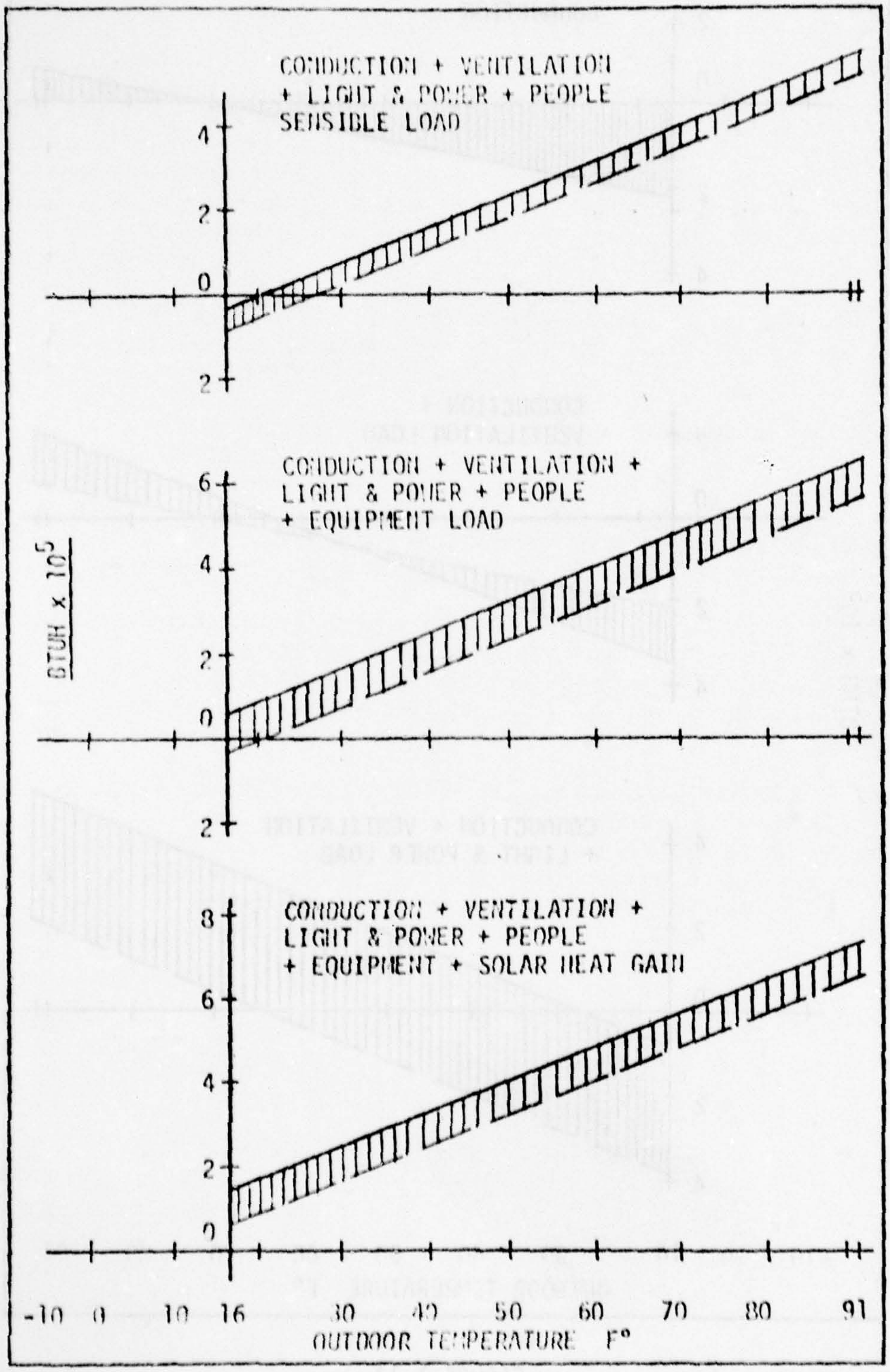


FIGURE 3-1B

MAJOR LOAD COMPONENTS

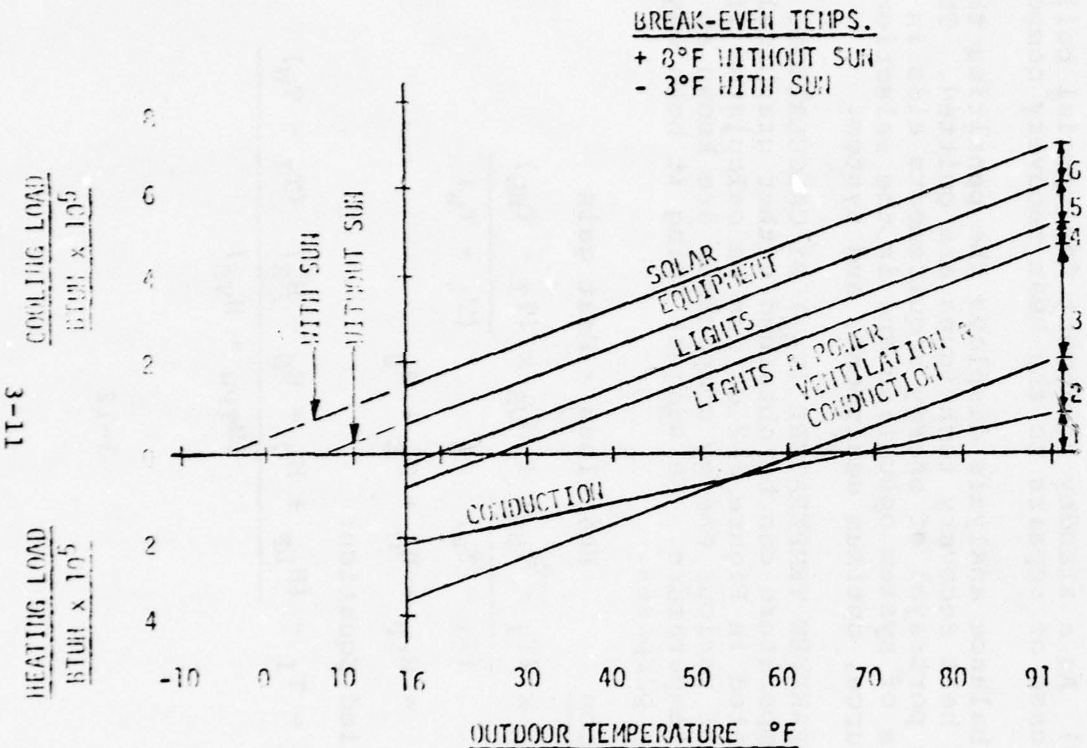


FIGURE 3-2

HEAT BALANCE DIAGRAM

IN A CONVENTIONAL AIR CONDITIONING SYSTEM, EVEN AT A WINTER DESIGN TEMPERATURE, THE INTERNAL ENERGY FROM LIGHTS, PEOPLE, SOLAR, EQUIPMENT, ETC., IS DISSIPATED TO THE ATMOSPHERE THRU THE COOLING TOWER. AT THE SAME TIME, WE BUY NEW ENERGY TO FURNISH THE BUILDING HEAT DEMAND.

THIS GRAPH ILLUSTRATES THE MAJOR COMPONENTS WHICH COMPRISE THE TOTAL AIR CONDITIONING LOAD OF THE BUILDING. THE BREAK-EVEN TEMPERATURE OF +8°F. INDICATES THAT, AT THIS AMBIENT TEMPERATURE, THERE IS AN ADEQUATE HEAT LOAD WITHIN THE BUILDING DURING OCCUPIED HOURS TO FURNISH ITS HEAT REQUIREMENTS SIMPLY BY REDISTRIBUTION. NOTE THAT WITH THE SUN, THE BUILDING CAN MAINTAIN THE DESIGN TEMPERATURE, EVEN WHEN THE AMBIENT IS AS LOW AS -3°F.

BUILDING
LOCATION: PHILADELPHIA, PA.
DIMENSIONS: 222' x 60' APPROX.
STORYS: TWO (2)
OCCUPANCY: 231
LIGHTING LEVELS: 3 WATTS/SQ.FT. (70F.C.)
+ 1/2 WATTS/SQ.FT. (FOR POWER)

eliminate the undesirable wastage which was inherent in the past conventional air conditioning systems, where the boiler was supplying the heat in the building and simultaneously heat was dissipated to the outside through cooling towers. Recognizing that the heat balance diagram is drawn for a building during occupied hours, supplementary heat is required for the following reasons:

(1) At winter design temperature when the outdoor temperature is so low that internal heat is not adequate to meet the project requirement.

(2) To furnish the heating requirements during nights, weekends and holidays when the building systems may be shut down.

(3) As a standby equipment for special buildings and in case of repairs to the heat recovery component.

A heat balance analysis displays the penalties that result if heat recovery techniques are omitted. The graphic portrayal of energy requirements aids in the analysis of system operation and in the selection of the fuel source, optimum equipment, and system.

3.2.3 BREAKEVEN TEMPERATURE (T_{BE}) BY CALCULATION. Breakeven temperature can be obtained either graphically as illustrated in Figure 3-2, or can be calculated if peak values of various energy components are known at winter design temperature. We suggest doing it both ways for checking purposes.

<u>Derivation</u> Heat loss = Heat gain

$$H_{TPW} \times \frac{(T_I - T_{BE})}{(T_I - T_W)} + H_{VS} \times \frac{(T_I - T_{BE})}{(T_I - T_W)}$$

$$= H_{LP} + H_O + H_E + H_S$$

Simplified Equation:

$$T_{BE} = T_I - \frac{(H_{LP} + H_O + H_S + H_E) \quad (T_I - T_W)}{(H_{TPW} + H_{VS})}$$

Above T_{BE} is with sun; T_{BE} without sun is obtained by substituting $H_S = 0$ in the above equation.

Example: The purpose of the example to calculate the breakeven temperature is to get the idea of its general value as applicable to an office building.

Location: Philadelphia, Pa.

Dimensions: 222' x 60' approx.

Storys: Two (2)

Areas: Gross total 26,230 ф , Net 23,136 ф

Occupancy: 231 (100 ф/person of net area)

Lighting Levels: 70 foot candles (3 watts/ф),
misc. power (additional 1/2 w/ф)

Most of the values for this example are taken from Run 1 of computer analysis. Only exception being that value of 100 ф/person is used instead of 50 ф/person and no electronic equipment load is considered since this applies to the laboratory area of the building. The following values were used for breakeven temperature calculations:

H_{TPW} - Peak winter conduction load = 207,150 BTUH

T_W - Winter design dry-bulb 16°F (97-1/2% frequency)

T_I - Inside winter design 70°F

H_{VS} - Sensible ventilation load 168,487 BTUH

H_{LP} - Light and power load 276,371 BTUH

H_O - People sensible load 57,750 BTUH

H_E - Equipment load 101,314 BTUH

H_S - Solar heat gain 96,074 BTUH

Calculation for T_{BE}:

(1) T_{BE} with sun

$$= 70 - \frac{(276{,}371 + 57{,}750 + 101{,}314 + 96{,}074)(70-16)}{207{,}150 + 168{,}487}$$

$$70 - \frac{531{,}509 \times 54}{375{,}637} = -6.4°F.$$

(2) T_{BE} without sun ($H_S = 0$)

$= +7.4°F.$

Summary:	From Graph	By Calculations
Breakeven temperature T_{BE} with sun	-3°F.	-6.4°F.
Breakeven temperature T_{BE} without sun	+8°F.	+7.4°F.

Section 3. ENERGY RECLAMATION COMPONENTS

3.3.1 COMPONENTS. Heat recovery components reclaim energy that might otherwise be wasted. For optimum energy use in HVAC systems the techniques to be considered should include:

(1) Exhaust Air Heat Recovery - Rotary air wheels, static heat exchanger, heat pipe, run-around system.

(2) Heat of Light Recovery.

(3) Refrigeration-Type Heat Recovery - Refrigeration coil, heat pumps, single and double condenser circuits.

3.3.1.1 Techniques. Heat recovery techniques should be considered for all systems greater than 25 tons. Economic evaluations should include run-around system, heat pipe, thermal wheel, cooling coils in exhaust ducts (chilled water/direct expansion type with double bundle or heat pump application), double bundle refrigeration machines, heat pumps, solid waste recovery boilers (Chapter 4), and heat of light.

3.3.2 EXHAUST AIR HEAT RECOVERY.

3.3.2.1 Rotary Air Wheels. These are rotary wheels that transfer heat between exhuast and makeup air streams, i.e., air-to-air heat recovery. They are available in two types, one transfers sensible heat and the other transfers both sensible and latent heat simultaneously. The latter is also known as a total transfer or enthalpy wheel. Economic justification for installing either of the two must be made in relation to the systems. In a system that has double bundle heat recovery machines, application of the wheel is only beneficial below the breakeven temperature (T_{BE} - see Section 2). The number of occupied hours below this temperature should be obtained for the location from NAVFAC P-89, "Engineering Weather Data." For further information on wheel design, efficiency construction and economics, see 1972 ASHRAE Guide and Data Book, Chapter 34. The application of wheels also must consider the relative duct location

of two air streams, effect on fan static pressure, space required by the wheel, and limitation on the contamination criteria for the building design. Heat recovery wheels are available in single units ranging from 300 to 50,000 CFM. Multiple units may be installed for larger capacities. Typical value of efficiency at equal flow ranges from 60 to 80 percent for both types of wheel. Air flow should be designed for counterflow for maximum efficiency and to keep the wheels clean, see Figure 3-3.

(1) Sensible Wheel: This transfers sensible heat only, in summer as well as winter. This is done by using heat absorbing corrugated metal mesh such as stainless steel or aluminum.

3.3.2.1.1 Temperature Calculations. Supply air temperature T_S °F. at the wheel outlet for equal supply and exhaust CFM is given by:

$$T_S = T_O + (T_E - T_O) \times \eta \text{ (wheel sensible efficiency)}$$

$$T_S = T_O + \frac{Q_E}{Q_S} \times (T_E - T_O) \times \eta \text{ (wheel sensible efficiency)}$$

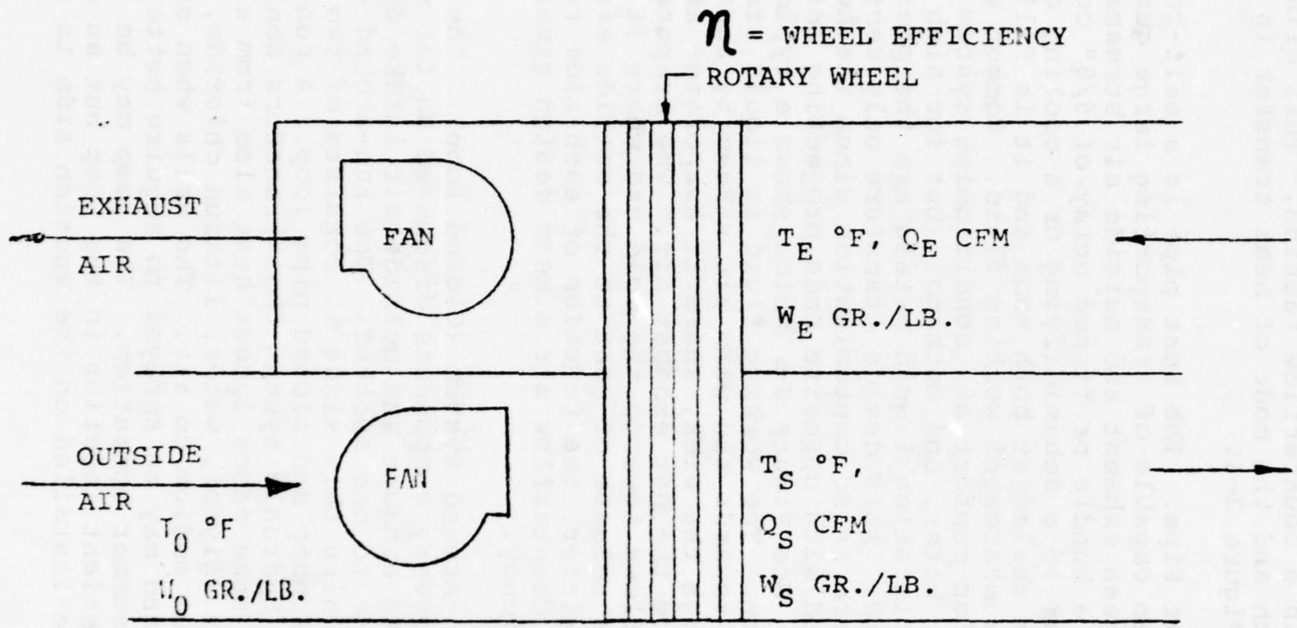
See Figure 3-7 for unequal CFM.

3.3.2.1.2 Enthalpy Wheel. This transfers both sensible and latent heat in summer as well as winter. It employs a desiccant impreganted material. A desiccant is defined as a material that has affinity to absorb moisture. A commonly used desiccant is lithium chloride (LiCl).

3.3.2.1.3 Temperature and Moisture Calculations. Temperature is given by the same formula as for the sensible wheel. Moisture in grains per pound is given by:

$$W_S = W_O + (W_E - W_O) \times \eta \text{ (wheel latent efficiency)}$$

Note: Sensible and latent heat transfer efficiency will vary for a given wheel operating under different conditions. Use corresponding efficiency figure in calculations.



T_O, T_S, T_E = DRY BULB TEMPERATURE, °F OF OUTSIDE AIR, SUPPLY AND EXHAUST AIR RESPECTIVELY.

W_O, W_S, W_E = MOISTURE CONTENT IN GRAINS PER POUND OF AIR IN OUTSIDE AIR, SUPPLY AND EXHAUST AIR RESPECTIVELY.

Q_S, Q_E = SUPPLY AND EXHAUST AIR QUANTITY, CUBIC FEET PER MINUTE.

FIGURE 3-3

HEAT RECOVERY WHEEL

3.3.2.2 Static Heat Exchanger. This device has no moving parts and sensible heat exchange takes place in alternate passages that carry exhaust and outside air through it in a counterflow fashion. This eliminates contamination and the mode of heat transfer is conduction. See Figure 3-4.

3.3.2.3 Heat Pipe. The heat pipe is a self-contained closed system capable of transporting large quantities of heat between exhaust and outside air streams. It consists of a bundle or finned array of 5/8" copper tubes similar to a dehumidifying or a cooling coil. Each tube is sealed at both ends and it is filled with a wick and a charge of working fluid. Common working fluid used for comfort air conditioning system includes refrigerant, water, and methanol; but for high temperature application liquid metals are the preferred working fluid. This device transfers only sensible heat and there is no contamination since the heat pipes are installed with opposite ends projecting into each air stream. See Figure 3-5 which shows a typical tube cross-section. The working fluid in liquid state is transferred towards the warm air stream by capillary action through the wick, where it evaporates absorbing heat from the hot exhaust air. The evaporated fluid then flows towards the cold end where it condenses with the release of heat to the outside air. This happens in winter; the function of each side reverses in summer. Counterflow air stream design gives optimum efficiency.

3.3.2.4 Run-Around System (Closed Loop). The exhaust air heat recovery components discussed so far necessitate that the exhaust and outside air intake ducts must be close to one another. The run-around system does not require this since it consists of two coil banks with a pump and closed pipe loop. A run-around system is a hydronic system that transfers sensible heat and in some cases latent heat also from air to fluid medium (glycol, water, lithium chloride, etc.) and back from medium to air. The coils when employed are finned and may be sprayed to acquire better recovery for summer operation. The pump may be located at any convenient location in the loop but an expansion tank must be installed on the suction side to allow

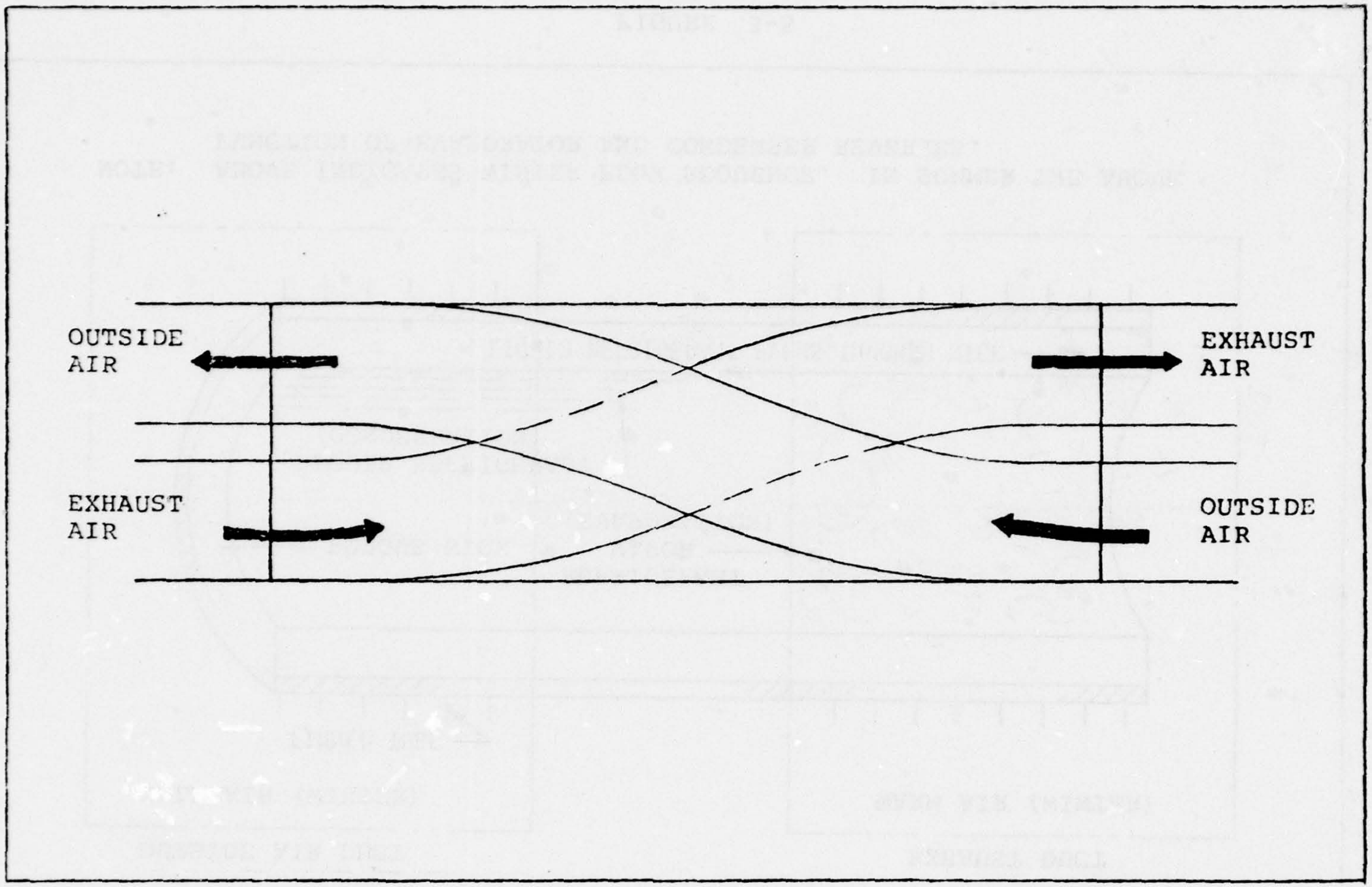
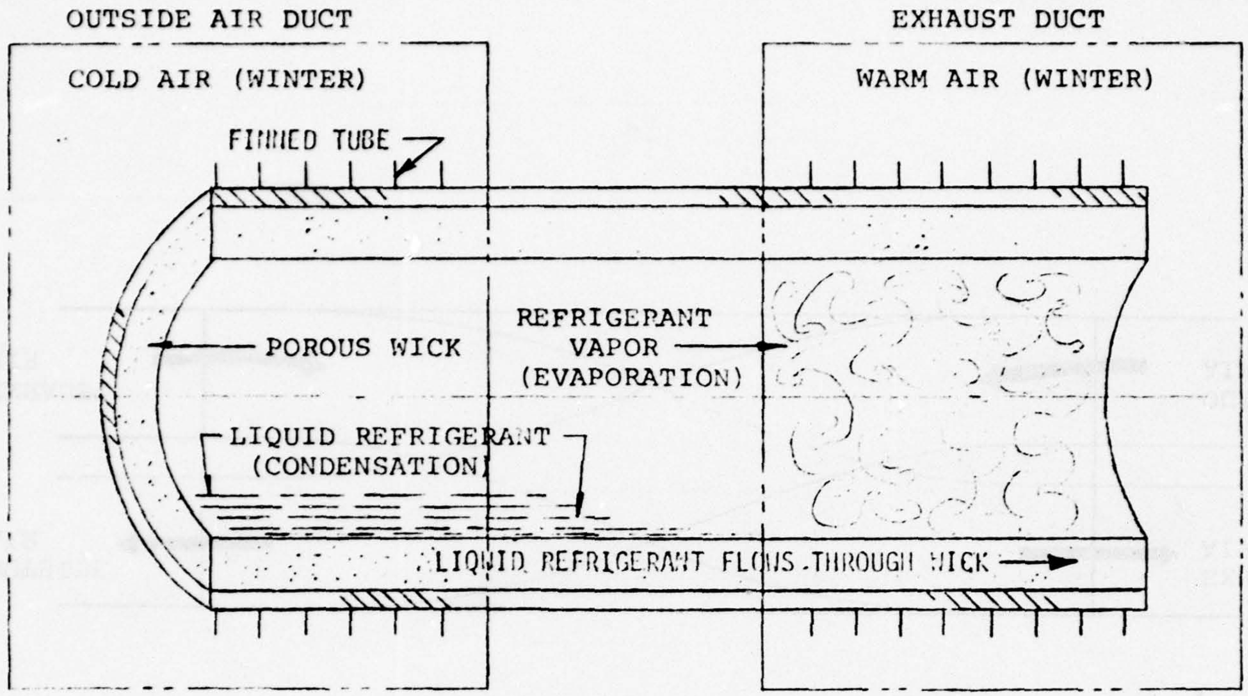


FIGURE 3-4

STATIC AIR-TO-AIR HEAT EXCHANGER



NOTE: ABOVE INDICATES WINTER FLOW SEQUENCE. IN SUMMER THE ABOVE FUNCTION OF EVAPORATOR AND CONDENSER REVERSES.

FIGURE 3-5

HEAT PIPE

for volumetric variation in the water and also to insure a net positive suction head. The run-around system may be used for the following applications:

(1) Coils in Separate Ducts. Exhaust to outside air exchange as shown in Figure 3-6, where the two coils are located in separate ducts, i.e., one coil is in the exhaust duct and the second coil is in the outside air intake duct.

(2) Coils in Air Handling Unit. Recovery within a single unit in summer operation by transferring heat from a precooling to a reheat coil as shown in Figure 3-7. In this case the two coils are in a single air handling system. The precooling coil reduces the load on the cooling coil. This device avoid using prime energy for reheat.

3.3.2.4.1 Run-Around System (Open Loop). This is a proprietary system developed by Midland-Ross Corporation and is referred to as a "Kathabar Twin-cel" system. This is an open system since the hygroscopic solution consisting of lithium chloride and sodium chromate (Kathene) comes in contact with both the outside and the exhaust air. It transfers both sensible and latent heat, (enthalpy exchanger). The fluid flows in each cell with the aid of a pump as shown in Figure 3-8 in a similar fashion to cooling tower flow, and has eliminators, packing materials and a basin to collect the solution. Kathene solution is a bacteriostatic liquid; this together with a thorough air scrubbing within the systems, makes it an efficient decontaminator of both intake and exhaust air streams.

3.3.2.5 Exhaust Reclaim Coil. Heat in the exhaust air may be recovered, if economical, by installing a cooling coil (chilled water) in the exhaust duct. Heat from the warm exhaust is transferred to water and could be utilized for heating purposes if double bundle heat recovery machine is incorporated in the central plant. Also see page 3-25, exhaust heat recovery by utilizing DX (refrigerant) coil in exhaust duct.

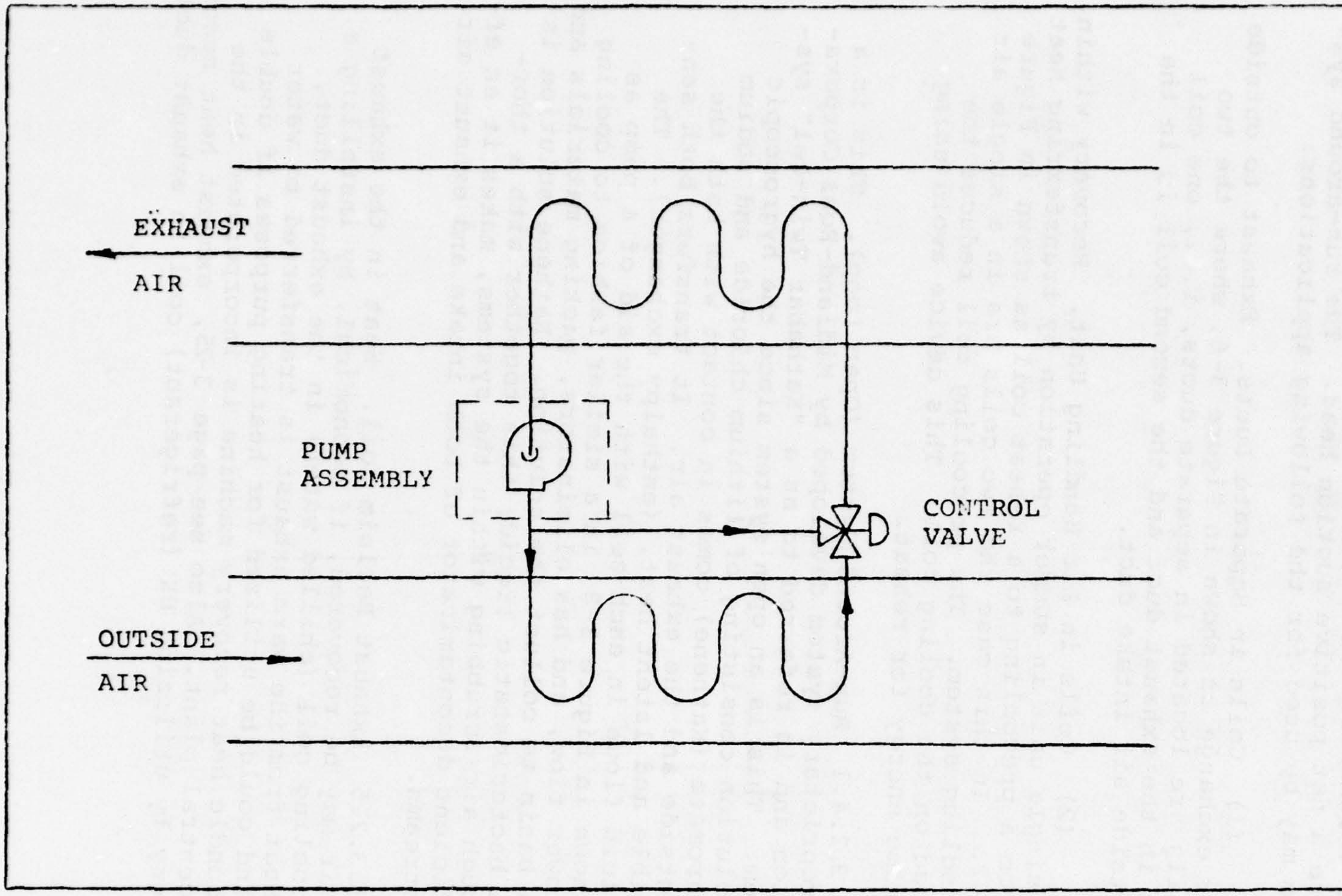


FIGURE 3-6

RUNAROUND SYSTEM (COIL IN SEPARATE DUCT)

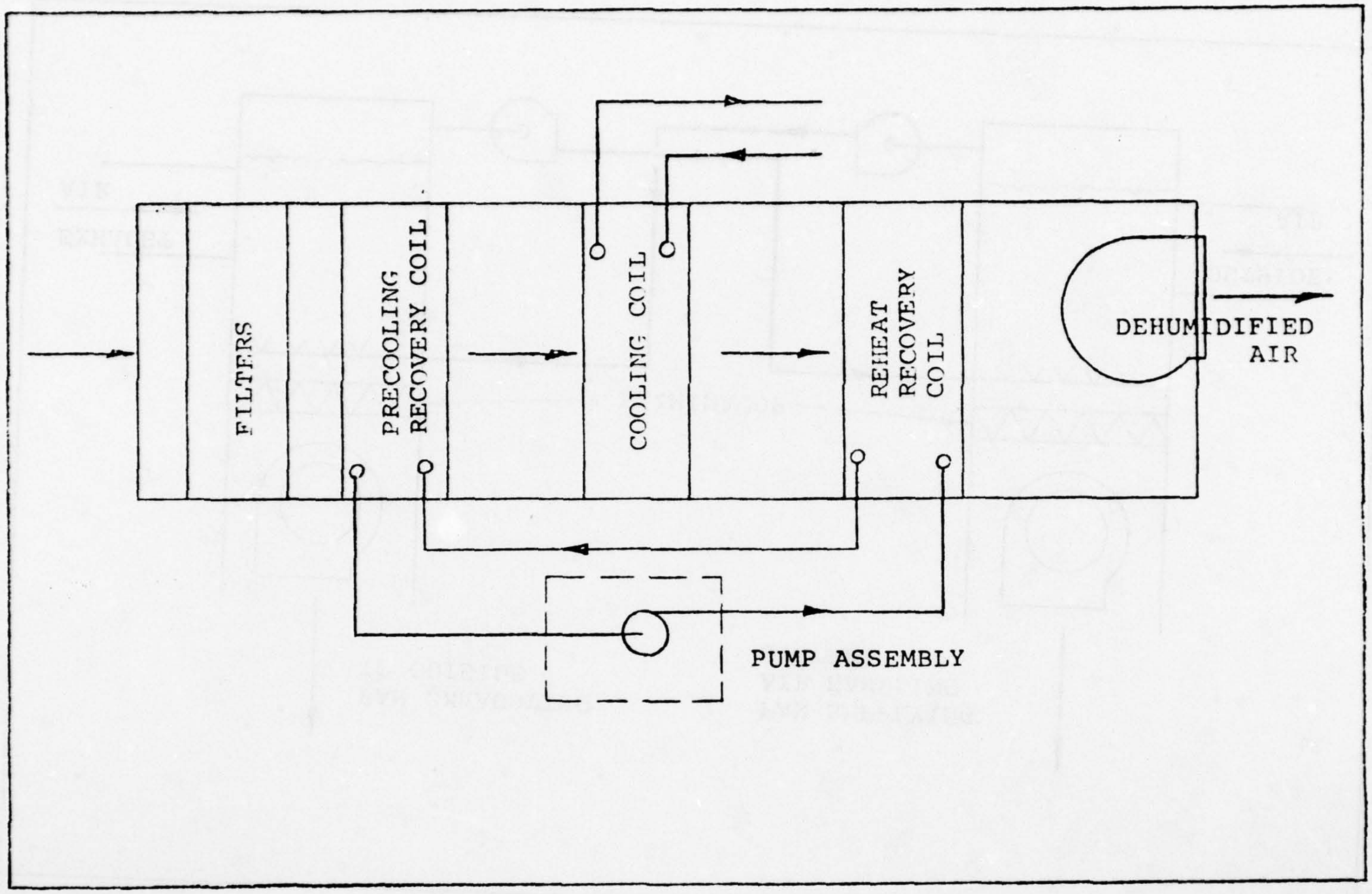


FIGURE 3-7

RUNAROUND SYSTEM (IN A SINGLE UNIT)

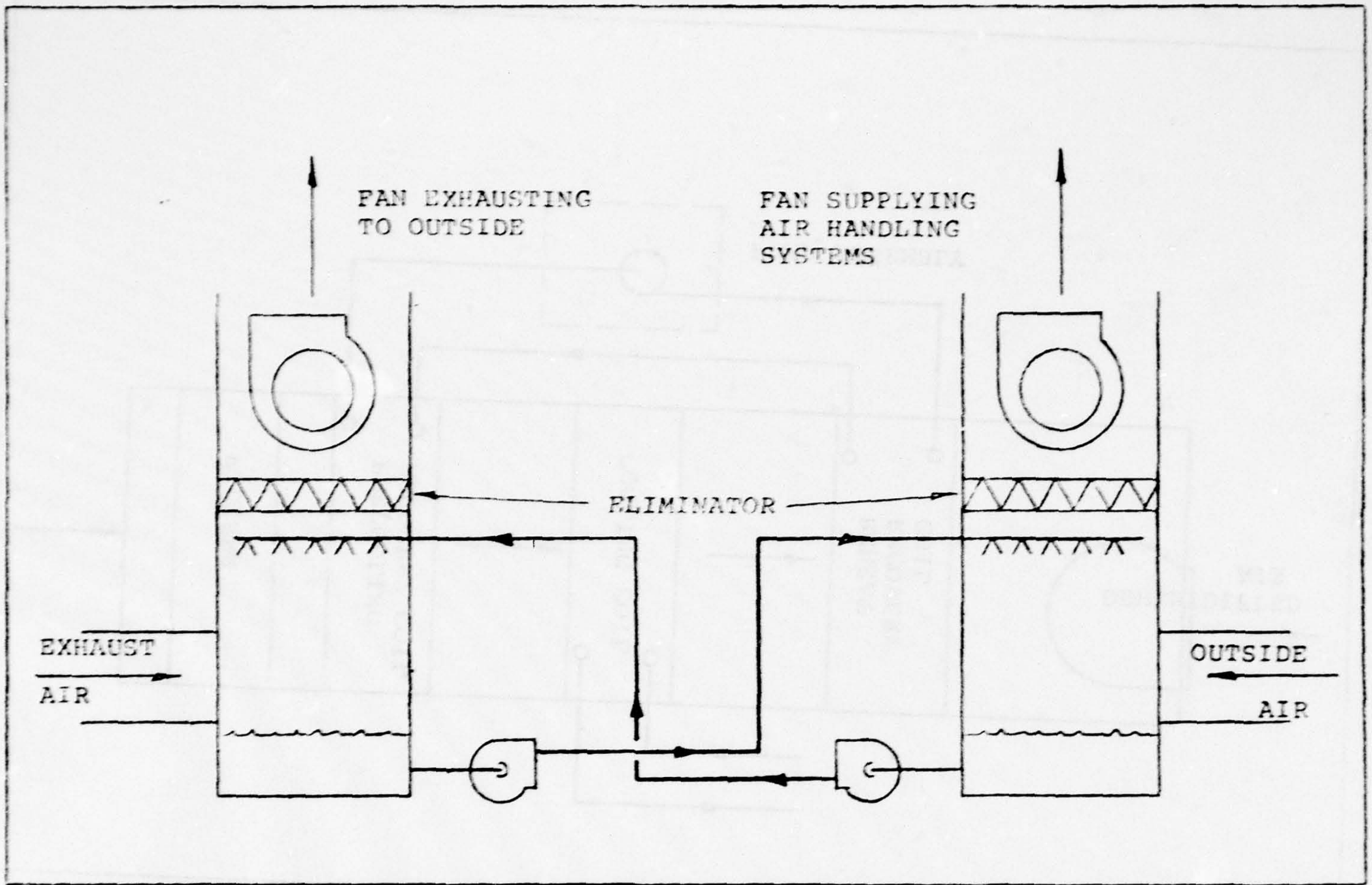


FIGURE 3-8

OPEN RUNAROUND SYSTEM (ENTHALPY TRANSFER)
(KATHABAR TWIN-CEL)

3.3.3 HEAT-OF-LIGHT (HOL) RECOVERY. The light load constitutes a large portion of the total cooling load and every endeavor to recover this portion is beneficial for energy optimization. The several ways employed in capturing this heat are:

(1) Light Troffer. Return all air through light troffer. See Figure 3-9. This method reduces the temperature of the luminaire surface and increases the life of ballast and the lamp. There is a reduction in the room load but the total cooling tonnage does not change. Air requirements in the space are reduced which in turn lowers the supply duct CFM, size, fan horsepower, noise level and air handling unit capacity. The heat dissipated above the ceiling plenum raises the plenum temperature, thus re-radiating a portion of heat back to the room. The remaining heat is lost to return air, to cold ducts within the plenum and to the floor above (assuming interior room without roof). To allow for this and also the wide variation in the value given by manufacturers as regards the percentage of heat dissipated above the ceiling from light, apply a factor of 0.75 to room load from lights when return air troffers are used.

(2) Direct Exhaust or Bleed Type System. In this system only the portion of air that is vented directly to exhaust is drawn through the lights. This system reduces the summer cooling load and is desirable for areas where the ventilation rate is high. The major portion of the supply air to the space is returned through wall or floor mounted registers.

(3) Ducted Air System. The ceiling plenum air can be used in connection with reheat induction system, see Figure 3-10.

3.3.4 REFRIGERATION TYPE HEAT RECOVERY.

3.3.4.1 Refrigeration Coil (DX). Heat is reclaimed by expending energy to raise the temperature level. This system is applicable where use of a reciprocating compressor is contemplated and where the heat output of compressor is about 1500 to 2000 KBH. Outside air can be used as the heat source during unoccupied period by

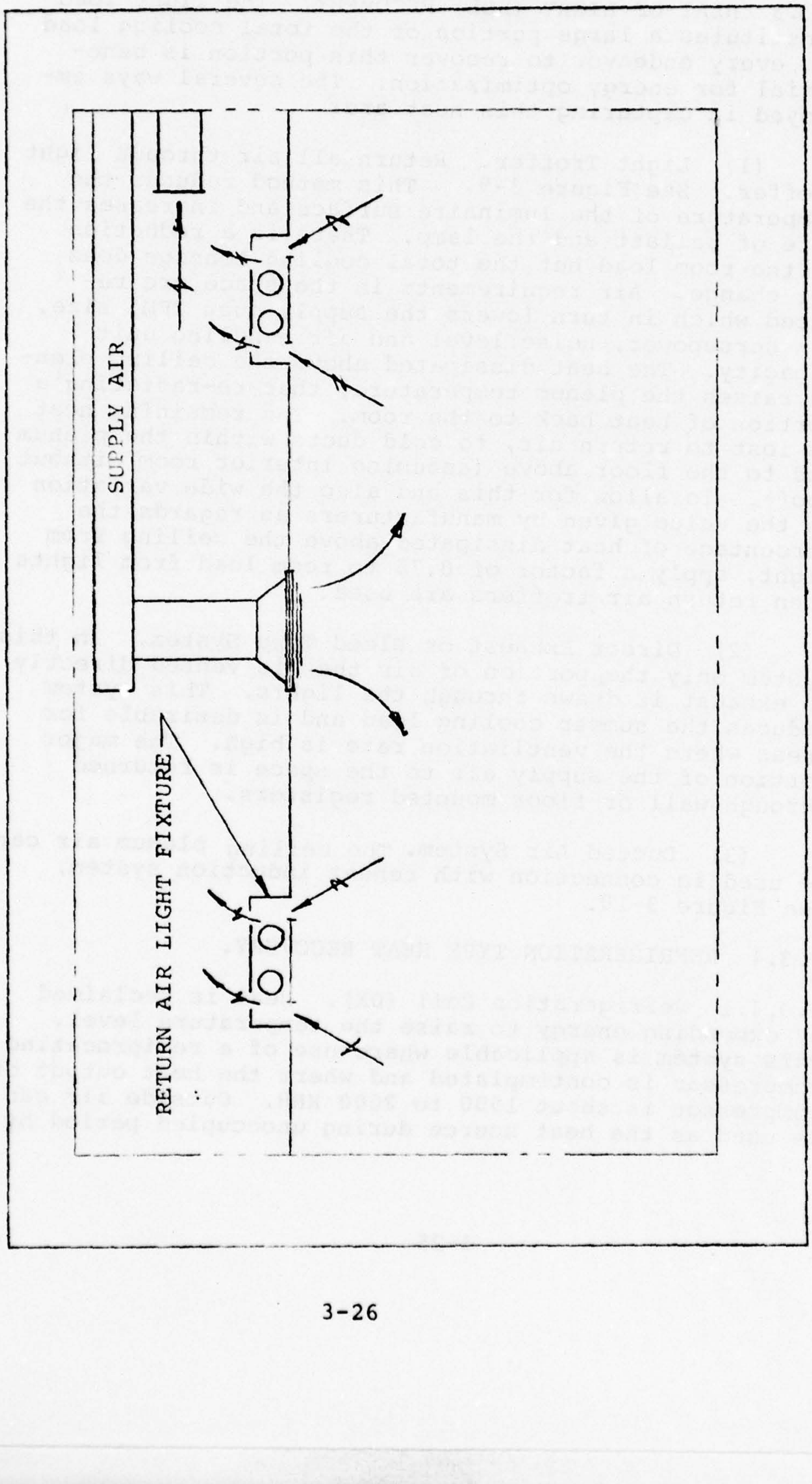


FIGURE 3-9

HEAT-OF-LIGHT RETURN

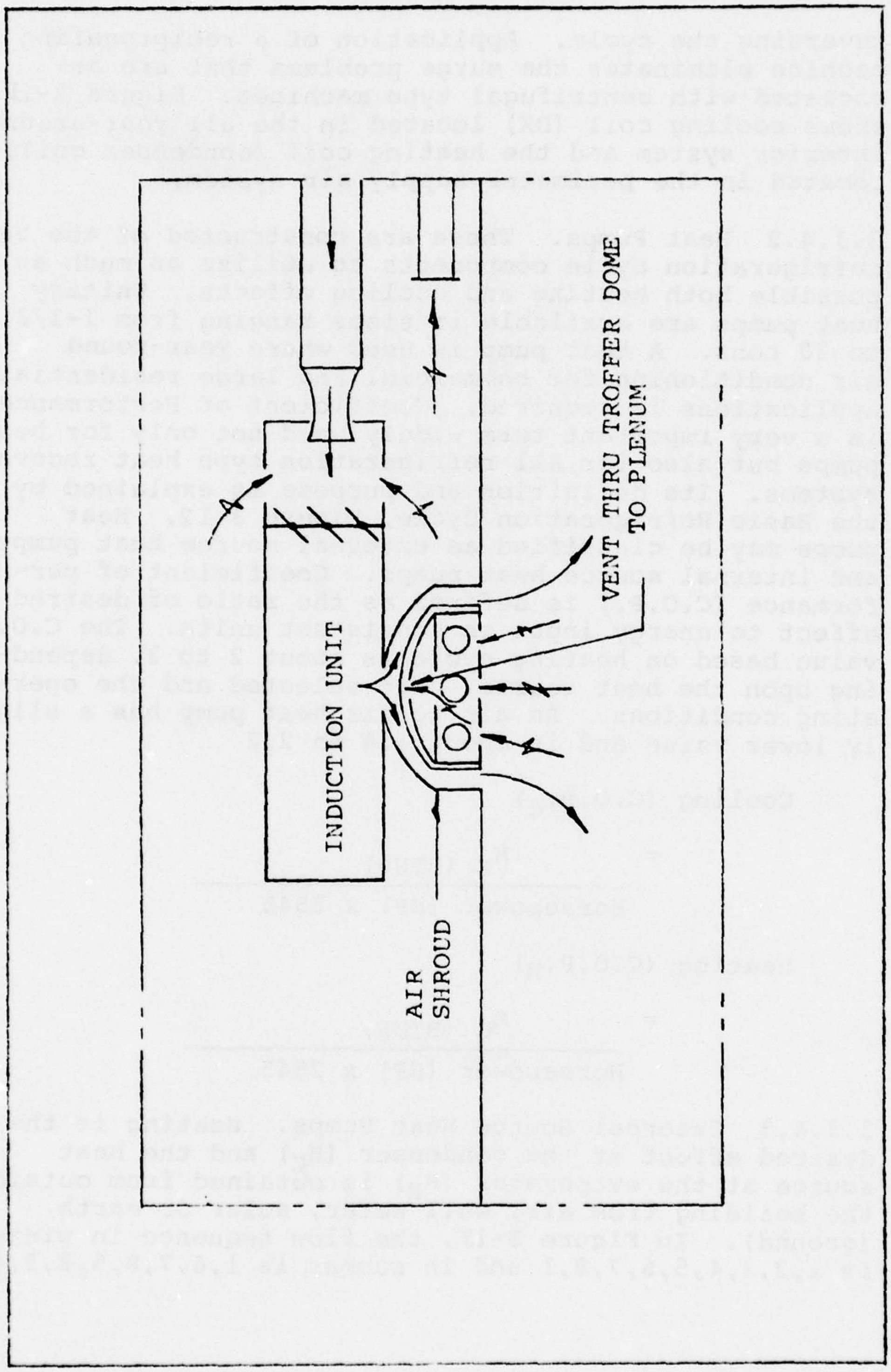


FIGURE 3-10

DUCTED AIR SYSTEM
(HEAT-OF-LIGHT)

reversing the cycle. Application of a reciprocating machine eliminates the surge problems that are associated with centrifugal type machines. Figure 3-11 shows cooling coil (DX) located in the all year-around interior system and the heating coil (condenser coil) located in the perimeter supply air system.

3.3.4.2 Heat Pumps. These are constructed of the basic refrigeration cycle components to utilize as much as possible both heating and cooling effects. Unitary heat pumps are available in sizes ranging from 1-1/2 to 20 tons. A heat pump is used where year-round air conditioning for commercial and large residential applications is required. Coefficient of Performance is a very important term widely used not only for heat pumps but also for all refrigeration type heat recovery systems. Its definition and purpose is explained by the Basic Refrigeration Cycle, Figure 3-12. Heat pumps may be classified as external source heat pumps and internal source heat pumps. Coefficient of performance (C.O.P.) is defined as the ratio of desired effect to energy input in consistent units. The C.O.P. value based on heating cycle is about 2 to 3, depending upon the heat source, unit selected and the operating conditions. An air to air heat pump has a slightly lower value and is about 1.4 to 2.2

Cooling $(C.O.P._C)$

$$= \frac{H_E \text{ (BTUH)}}{\text{Horsepower (HP)} \times 2545}$$

Heating $(C.O.P._H)$

$$= \frac{H_C \text{ (BTUH)}}{\text{Horsepower (HP)} \times 2545}$$

3.3.4.3 External Source Heat Pumps. Heating is the desired effect at the condenser (H_C) and the heat source at the evaporator (H_E) is obtained from outside the building from air, well water, solar or earth (ground). In Figure 3-13, the flow sequence in winter is 1,2,3,4,5,6,7,8,1 and in summer is 1,6,7,8,5,2,3,4,1.

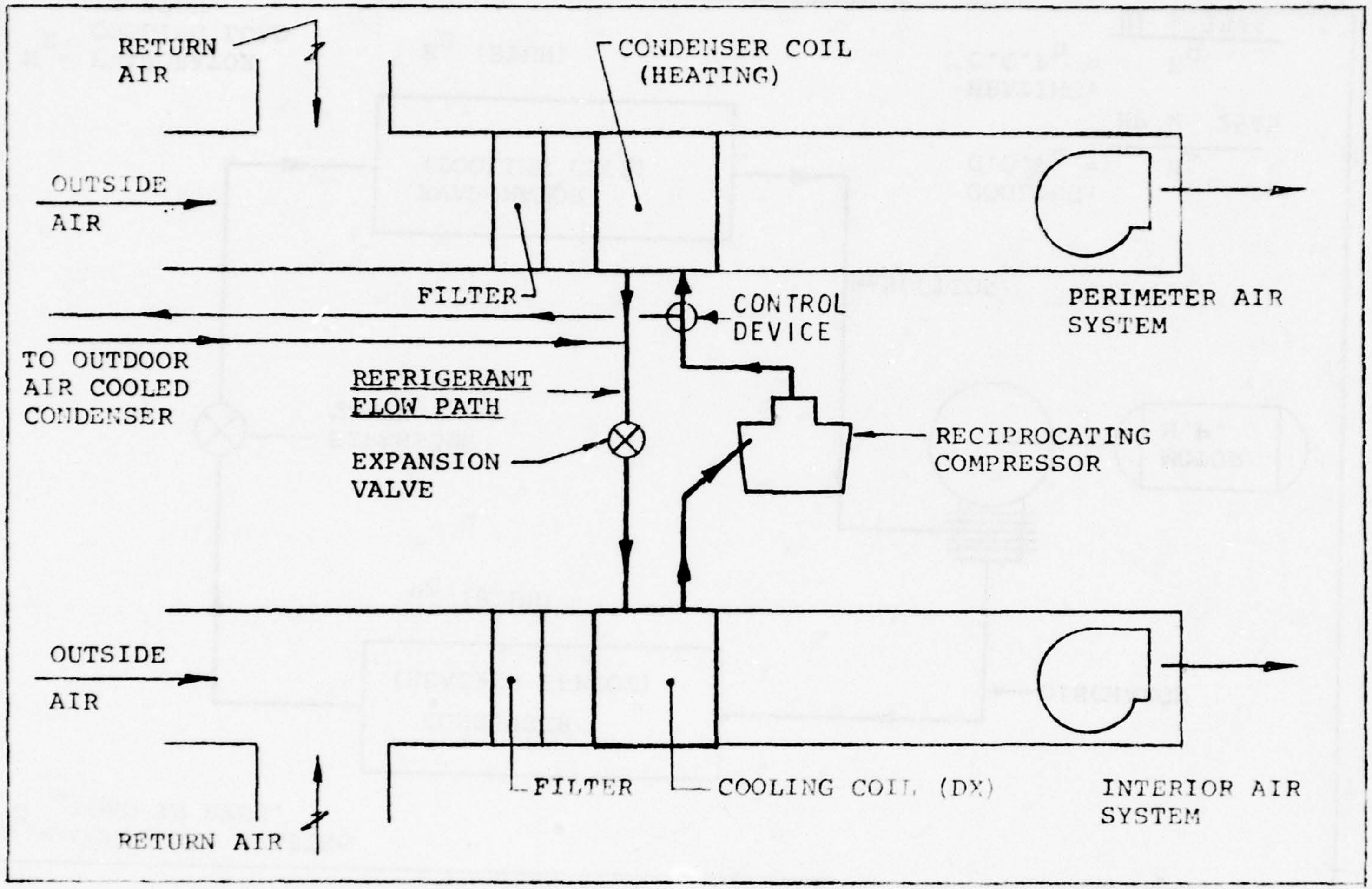


FIGURE 3-11

REFRIGERATION COIL FOR HEAT RECOVERY SYSTEM

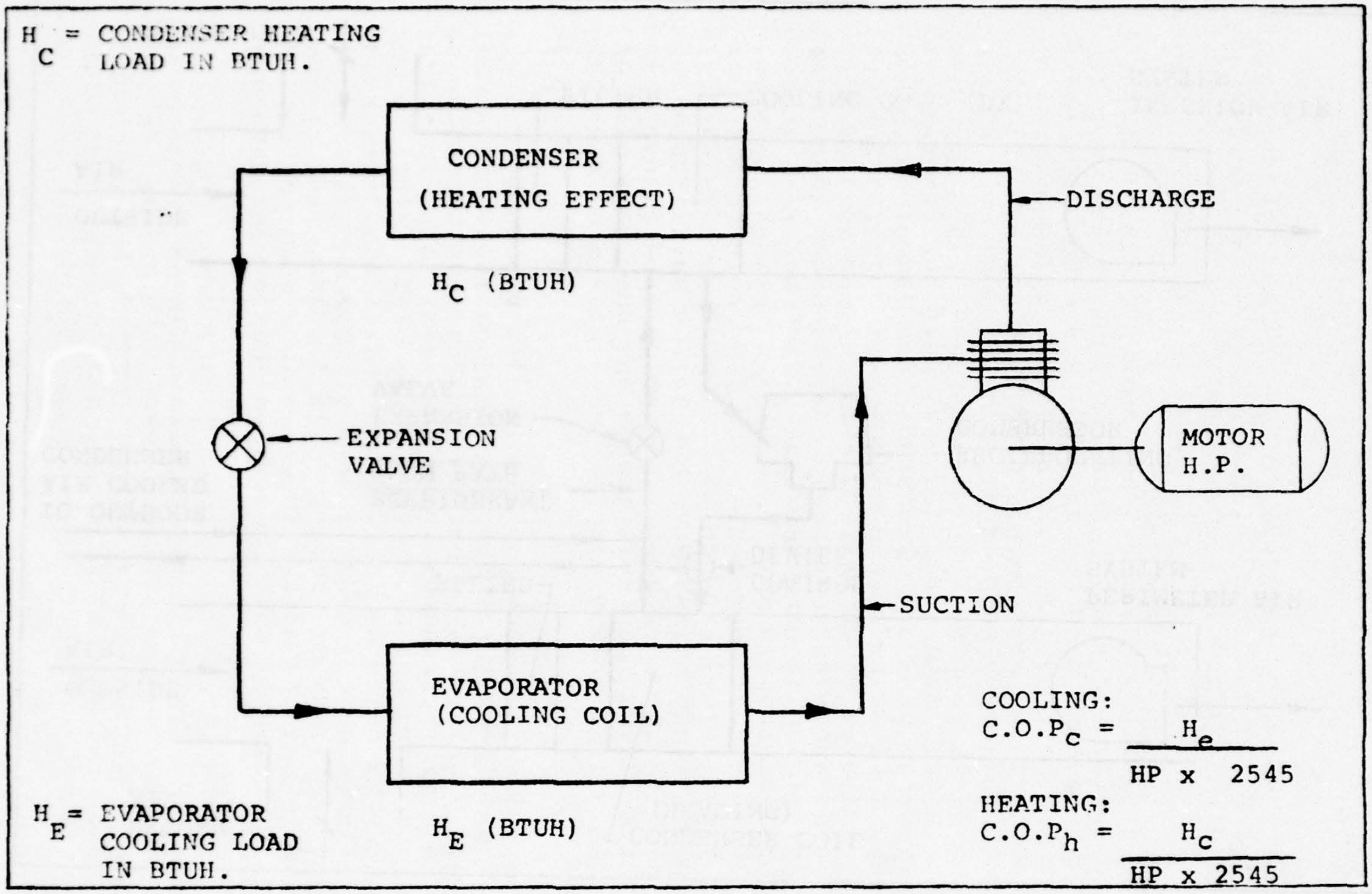


FIGURE 3-12

BASIC REFRIGERATION CYCLE

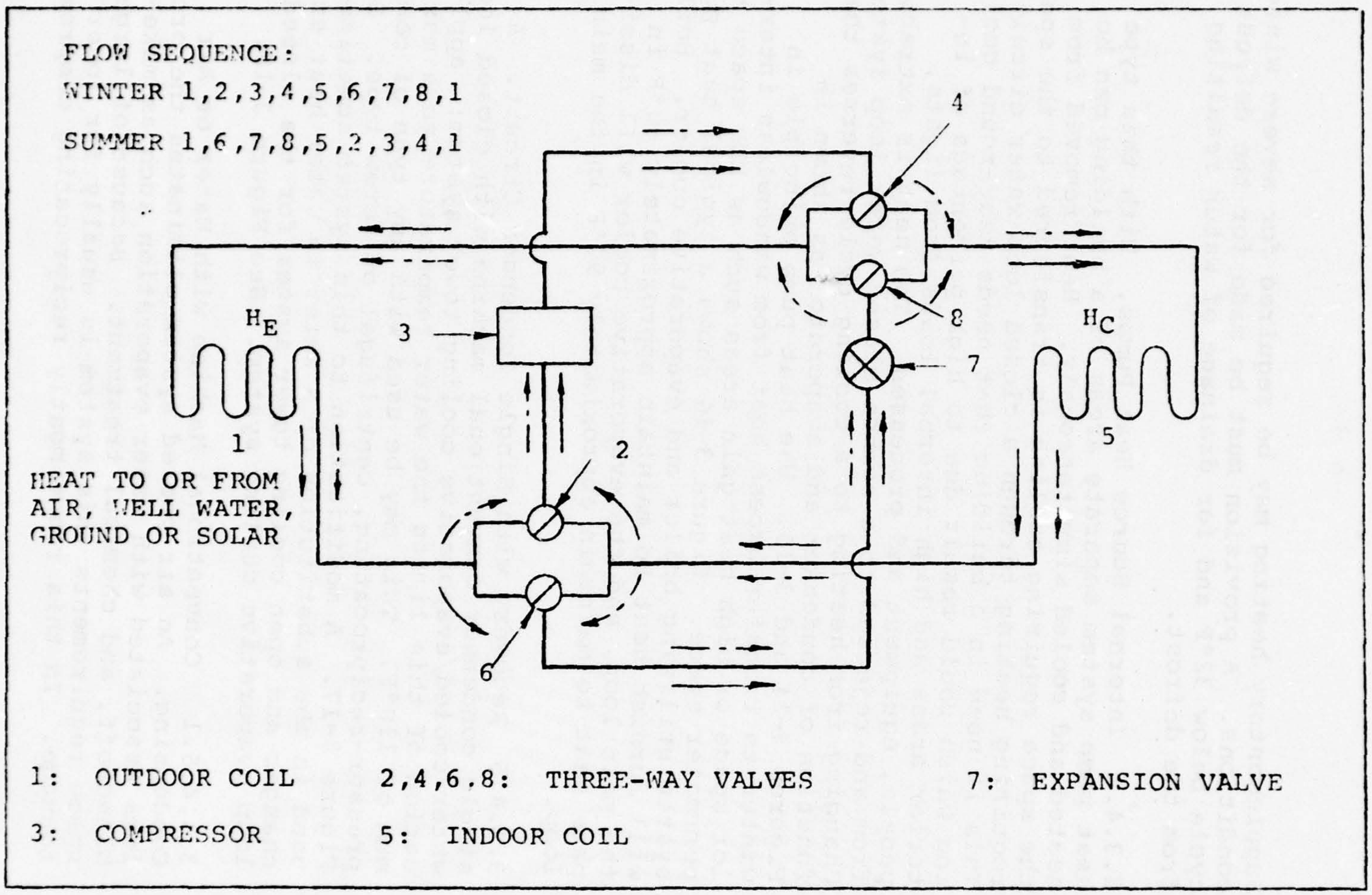


FIGURE 3-13

EXTERNAL SOURCE HEAT PUMP

Supplementary heating may be required for severe winter conditions. A provision must be made for the defrost cycle below 32°F and for drainage of water resulting from the defrost.

3.3.4.4 Internal Source Heat Pumps. With this type heat pump system separate areas of a building can be heated and cooled simultaneously. Heat removed from the space requiring cooling is transferred to the space requiring heating through a closed loop water circuit. This is used in a building that needs year-round cooling which could result due to high percentage of interior areas and high internal loads from lights, people, equipment and processes. The heat is extracted from and rejected to a common closed water loop system. Changing from heating to a cooling cycle reverses the function of condenser and evaporator as shown in Figures 3-14 and 3-15. Use heat pump principle in winter to transfer excess heat from windowless interior space or high heat gain areas such as EDP space to perimeter space. Figure 3-16 shows a typical heat pump system utilizing boiler and evaporative cooler. Boiler will furnish heat to maintain approximately 60°F in the main loop, and the evaporative cooler will dissipate heat to maintain approximately 90°F in the main loop.

3.3.4.5 Recovery with Single Condenser Circuit. A single condenser conventional machine with closed loop water cooled/evaporative cooling tower system: application of this limits the water temperature to a maximum of 110°F. This may be used with any type of compressor-reciprocating, centrifugal or screw type. See Figure 3-17. A modification to this system sometimes used is the substitution of a water to water heat exchanger and open cooling tower system for the closed loop evaporative cooling system. See Figure 3-18.

3.3.4.5.1 Conventional Machine with Water or Air Condensing. An air cooled system eliminates the problems associated with water evaporation such as make-up, bleed-off, and chemical treatment. Because of large space requirements this system is usually for lower tonnage. In this range mostly reciprocating compres-

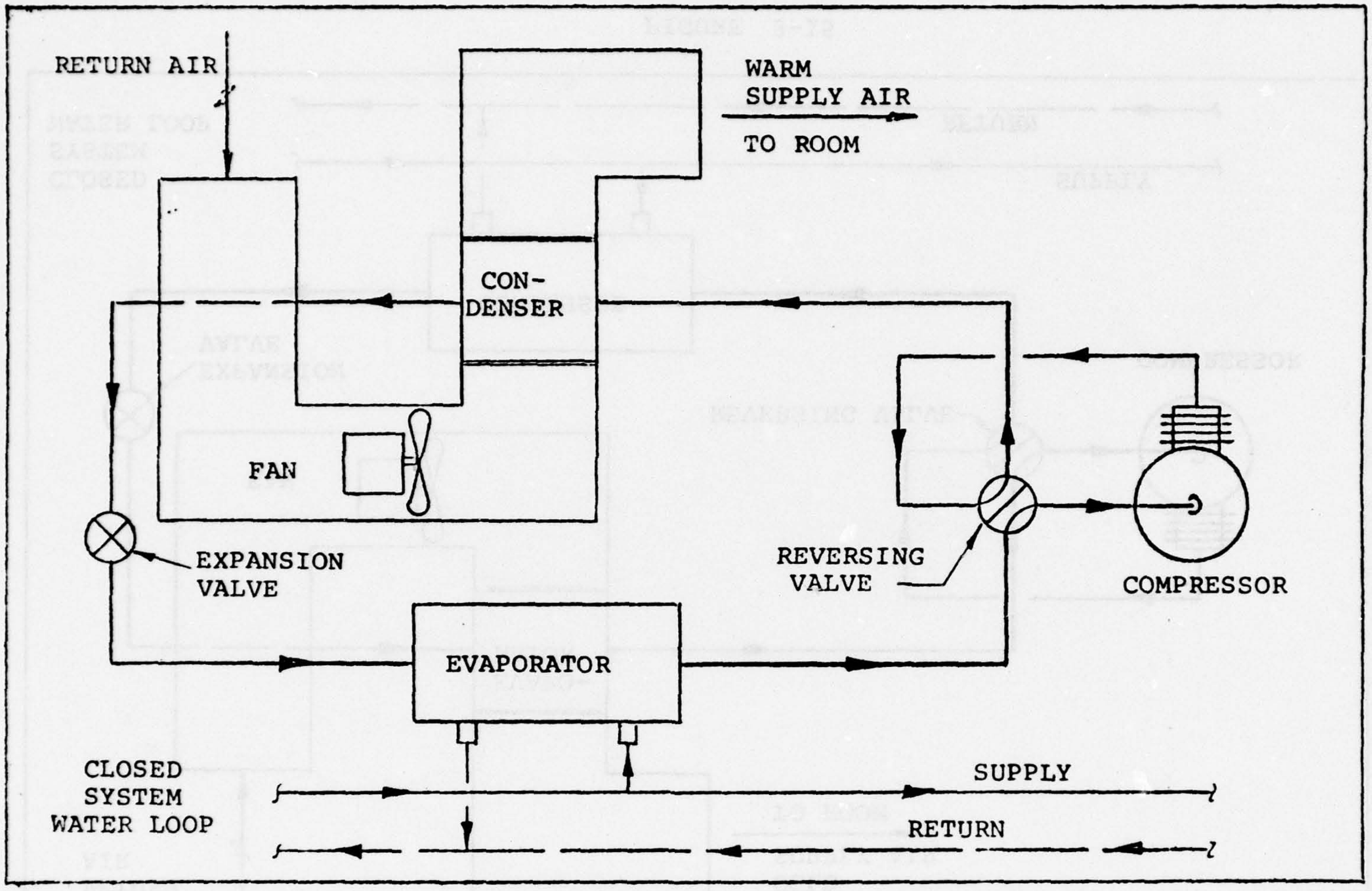


FIGURE 3-14

HEAT PUMP - HEATING MODE (INTERNAL SOURCE, CLOSED LOOP)

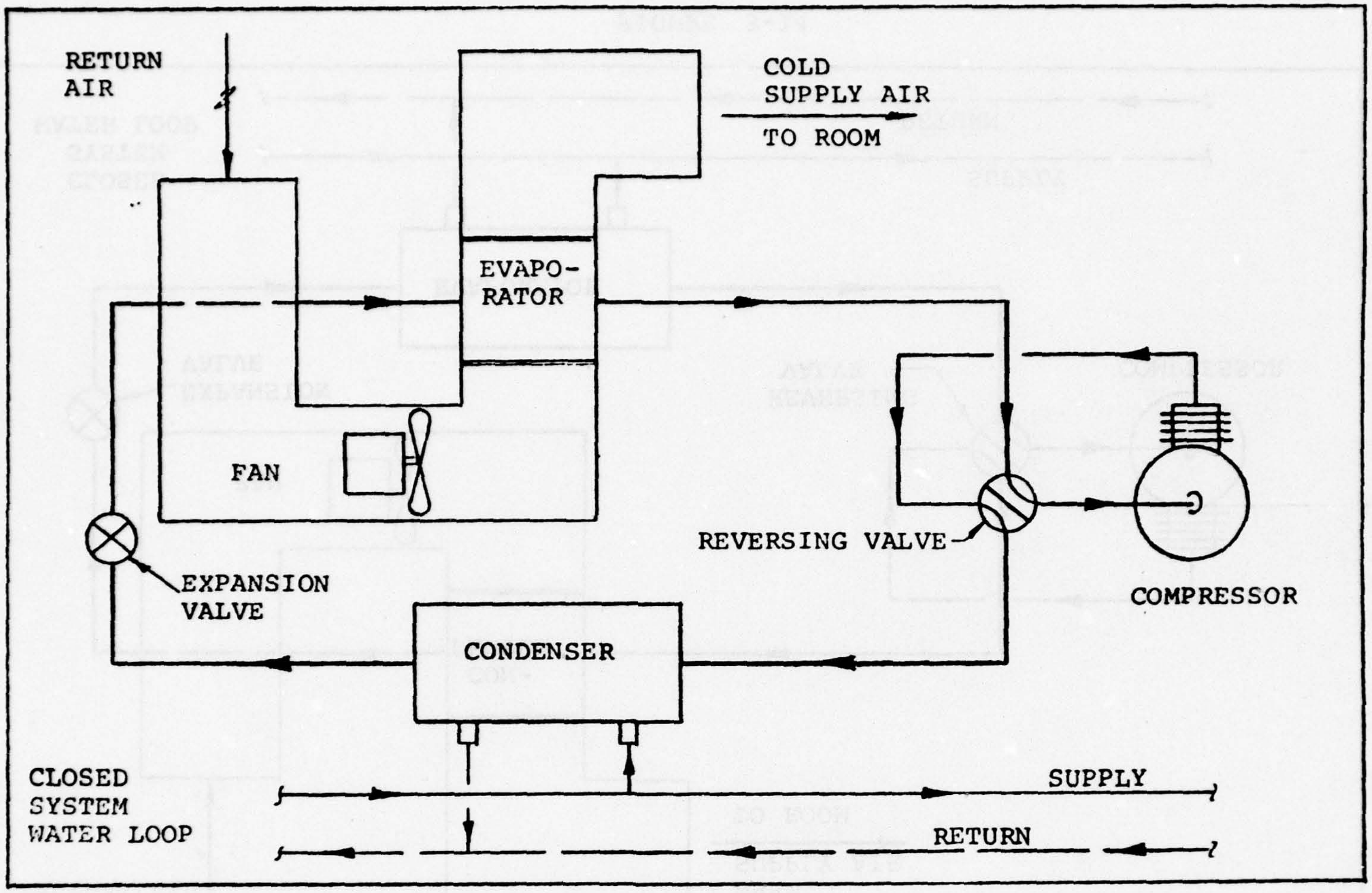


FIGURE 3-15

HEAT PUMP - COOLING MODE (INTERNAL SOURCE, CLOSED LOOP)

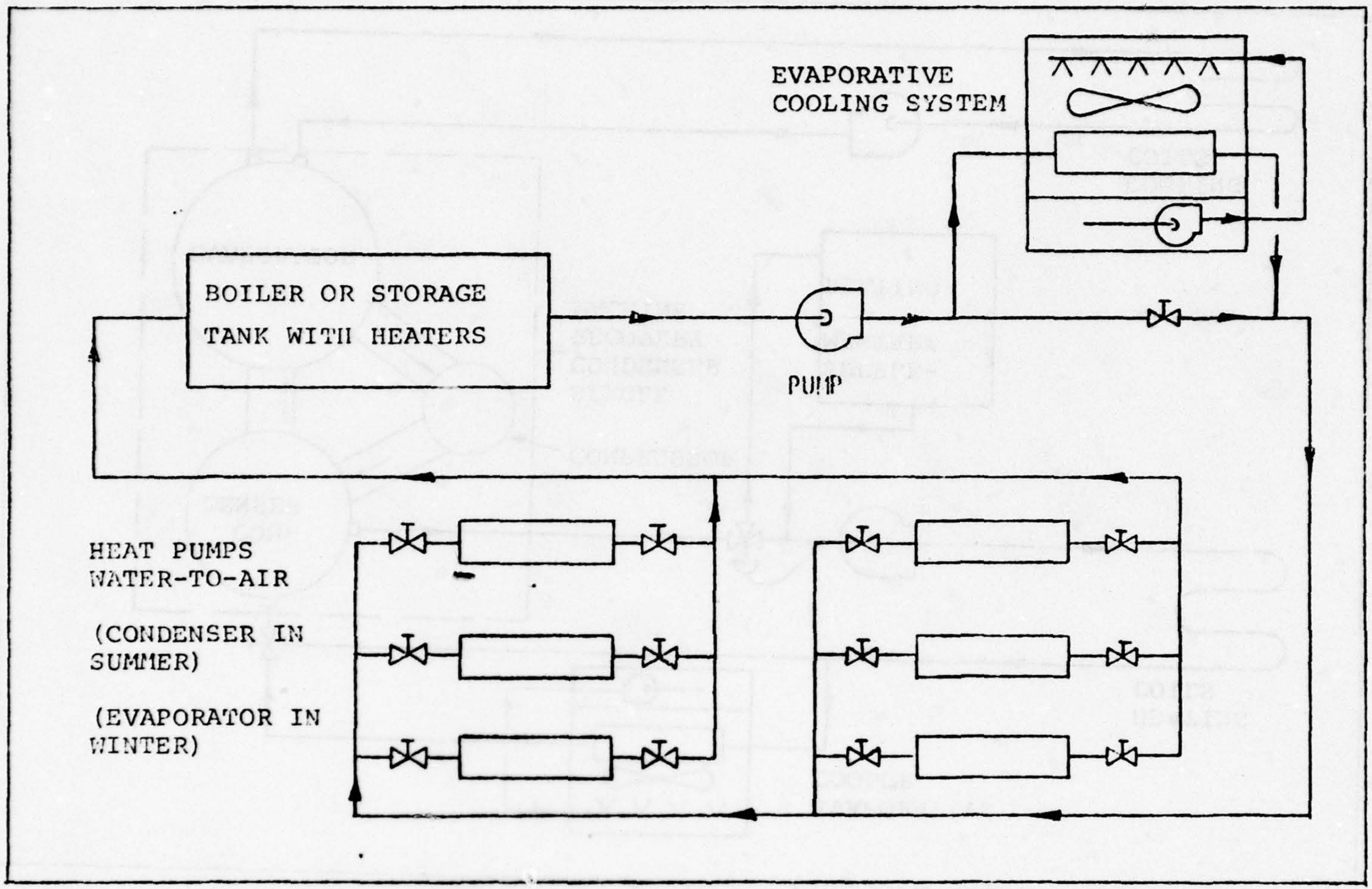


FIGURE 3-16

TYPICAL HEAT PUMP SYSTEM WITH BOILER AND EVAPORATIVE COOLER

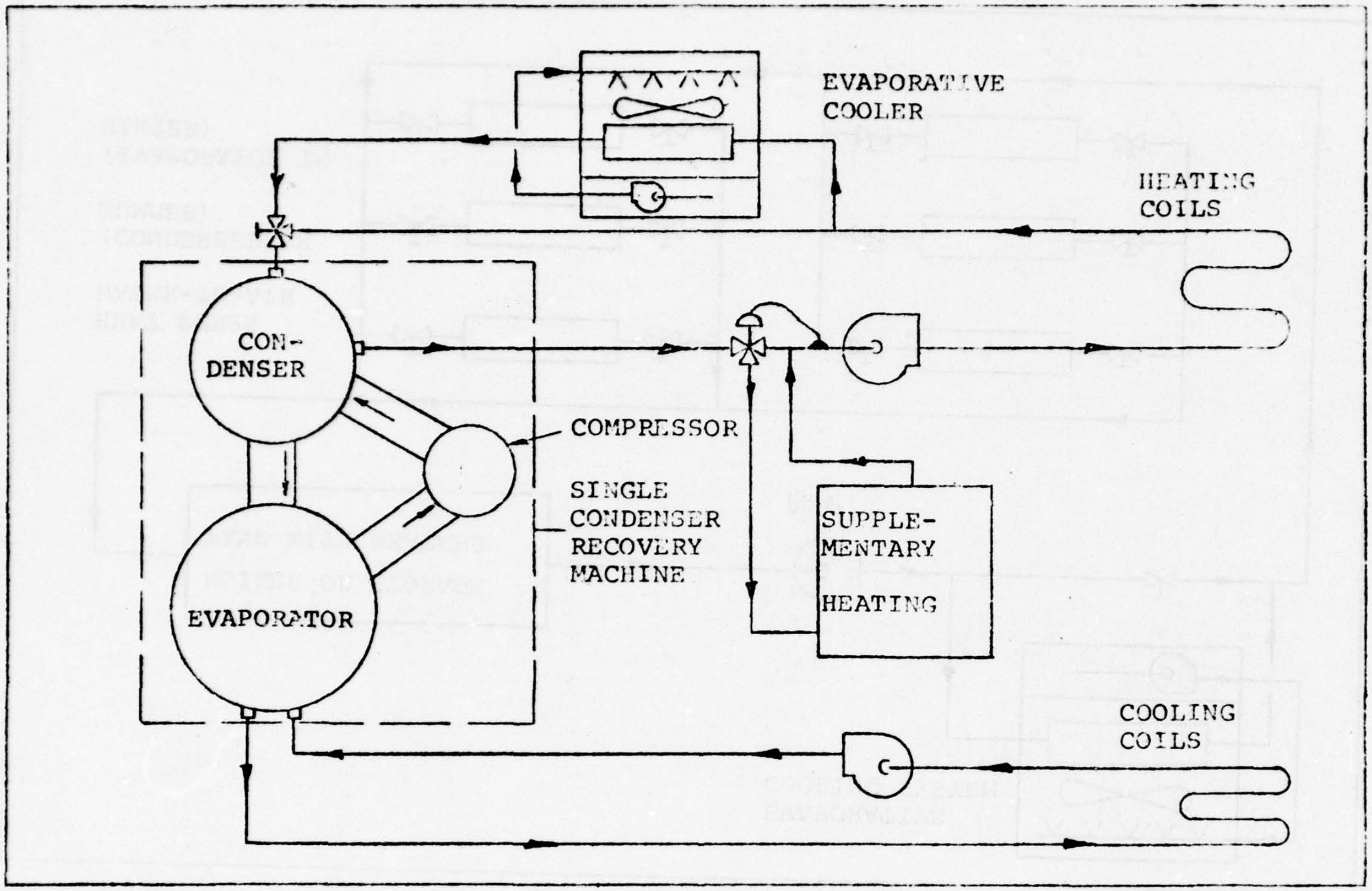


FIGURE 3-17

SINGLE CONDENSER WITH EVAPORATIVE COOLING SYSTEM

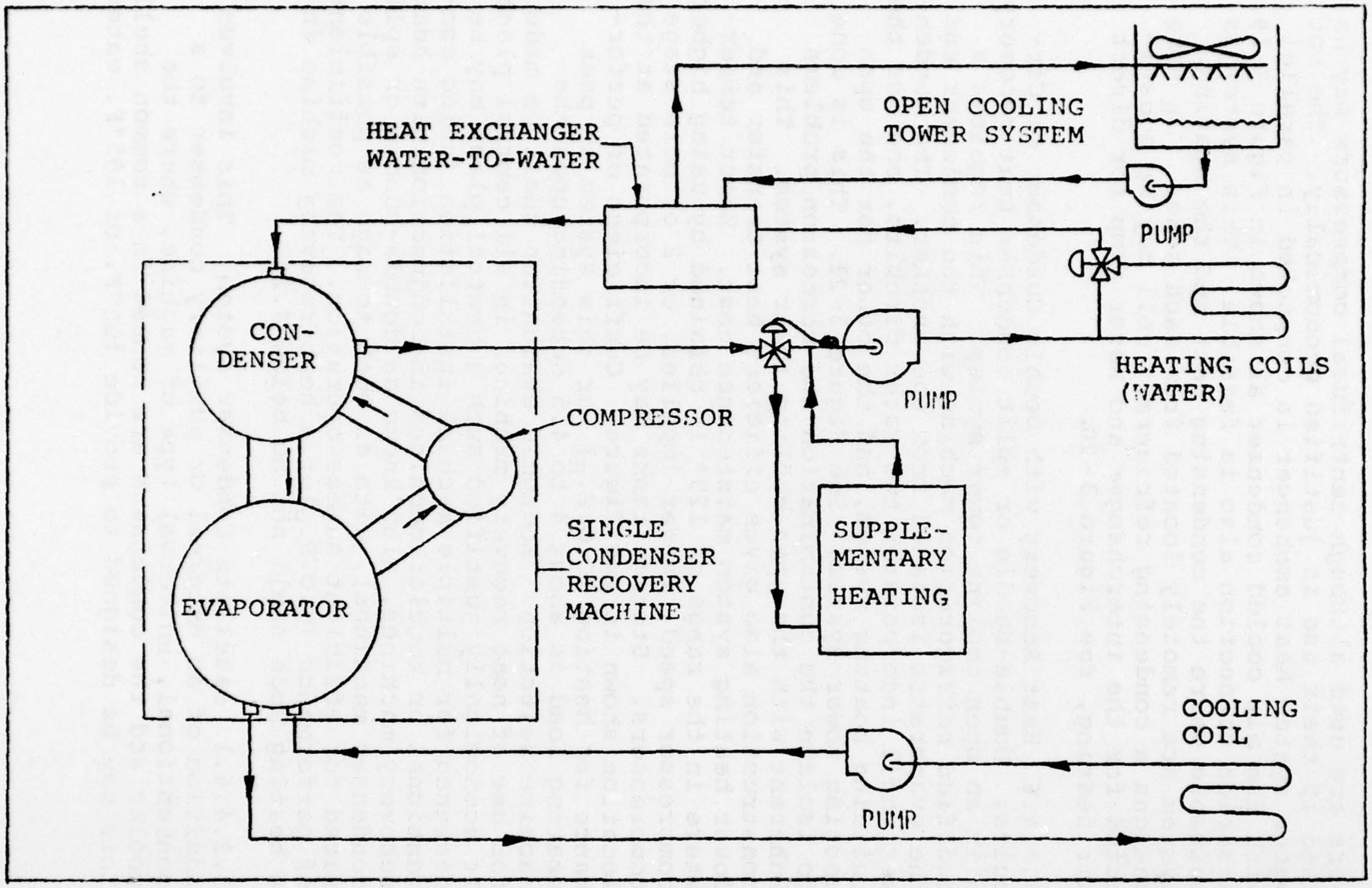


FIGURE 3-18

SINGLE CONDENSER WITH HEAT EXCHANGER AND OPEN TOWER

sors are used although centrifugal compressors may be used if their use is justified economically. The hot water system heat exchanger is connected in parallel with the air cooled condenser as shown in Figure 3-19. A series connection also is feasible. This system is suitable where the condensing unit and the heating system are remotely located from each other. In some designs a condensing refrigerant coil may be substituted for the interchanger and water pump for direct air heating, see Figure 3-20.

3.3.4.6 Heat Recovery with Double Condenser or Circuits. Double-bundle or split condenser heat recovery with an open cooling tower system: This requires a modified refrigeration machine with the condenser and the evaporator isolated from one another. The condenser shell incorporates two water circuits, one for the building heating system, and the other for the open cooling tower system. See Figure 3-21. This is done to isolate the contamination and corrosion problems inherent with the open cooling tower system. This construction also gives efficient heat transfer and lower heating system maintenance cost. Water temperature in the range of 125° is obtained by using higher compressor speed, larger impeller, or 2 or more stage compressors. Storage tanks may be incorporated at the location shown in the figure. Coefficient of performance for heating ($C.O.P._H$) for this system at peak heating load is about 4 to 4.5 depending upon the machine selection. Economic evaluation shall be made for use of heat recovery machines in all central plants. If economically justified such a central plant may be designed for multiple machine installation (using conventional or regular machines in conjunction with heat recovery machines, also known as double-bundle or split condenser machines), with as much tonnage as possible sized for efficient summer operation. The coefficient of performance ($C.O.P._H$)of a heat recovery machine in a heating mode shall not be below 4.2.

3.3.4.6.1 Satellite Condenser System. This involves addition of an external or auxiliary condenser to a conventional, universal type of machine, where the cooler and the condensers are housed in a common shell. This may be designed to provide 100°F. or 105°F. water

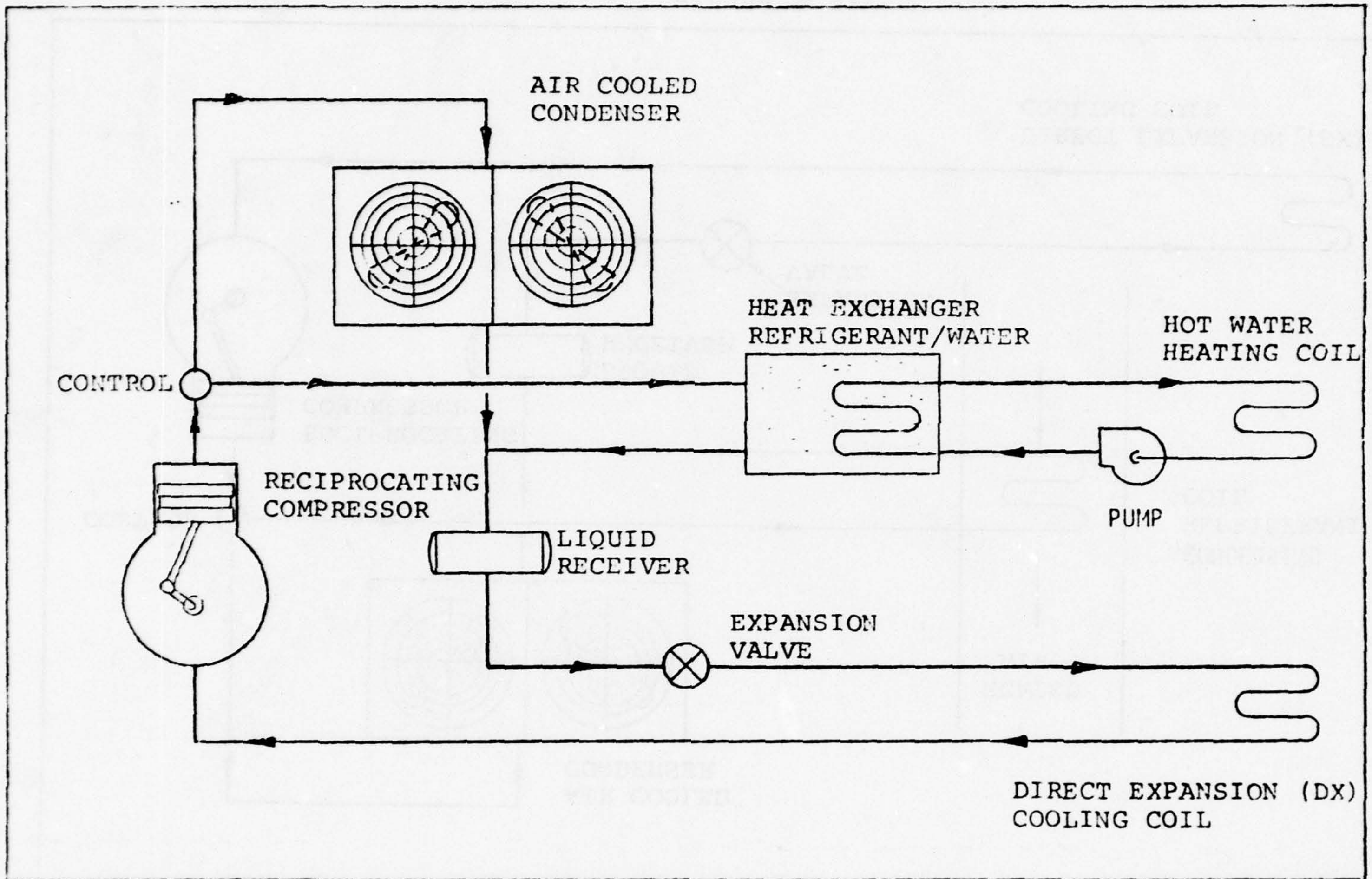


FIGURE 3-19

AIR COOLED CONDENSER WITH REFRIGERANT TO WATER HEAT EXCHANGER

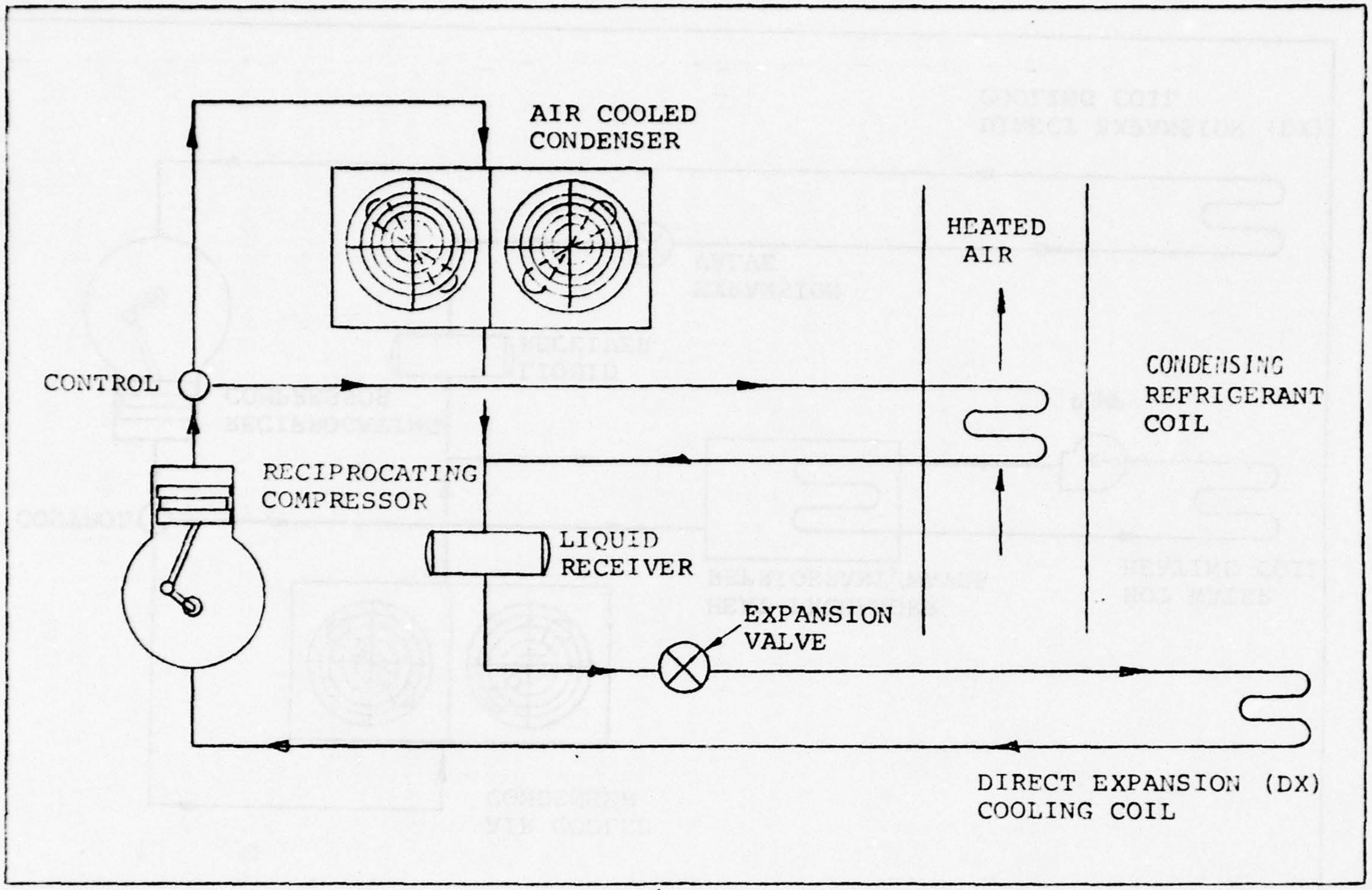


FIGURE 3-20

AIR COOLED CONDENSER WITH HEATING REFRIGERANT COIL
(MODIFIED SYSTEM)

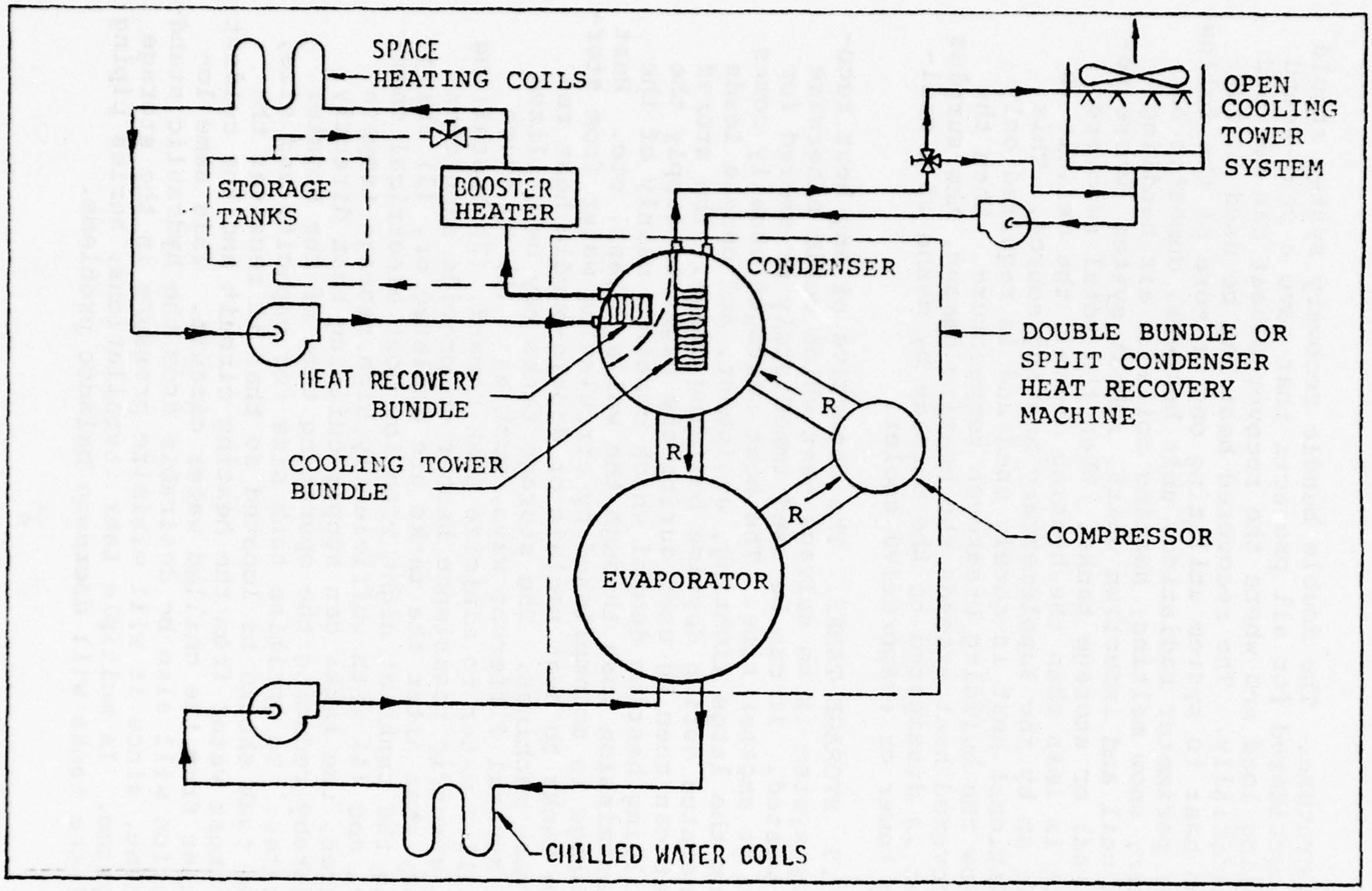


FIGURE 3-21

DOUBLE BUNDLE OR SPLIT CONDENSER HEAT RECOVERY WITH OPEN COOLING TOWER SYSTEM

temperature. The double bundle recovery system should be considered for all projects that have a year-round cooling load and where the recovered heat can be used beneficially. The recovered heat may be used to furnish heat to system utilizing one or more of the following: perimeter radiation, unit heaters, domestic hot water, snow melting, heating coils in air handling, fan coil and induction units, reheat system (where required) or storage tanks. When the total recovered heat is less than the heating demand, the deficit is made up by the supplementary heating source. This additional heat is rarely used and is required only below the building breakeven temperature. When the recovered heat exceeds the heating demand, the surplus heat is dissipated to the outside by means of a cooling tower or evaporative cooler.

3.3.5 STORAGE TANKS. The objective of any heat recovery system is to salvage heat which would otherwise be wasted. It can be used immediately or stored for use at another time. The heat salvaged usually comes from the large lighting, equipment, and people loads generated during daytime building usage. The stored heat can then be used during the night to supply the building heating demand which consists mainly of the transmission loss through the walls, glass, etc. Heat storage is accomplished by circulating water from storage tanks to heat reclaim or double-bundle heat recovery machines. The storage tanks may be utilized in several different ways, such as: (1) to store chilled water to minimize peak demand, (2) installing an electric resistance heater to provide supplementary heat after the tanks are depleted or, (3) charging the tanks at night with low cost electrical energy, and (4) with sufficiently high storage temperatures, the tanks can supply building heat directly, thereby reducing the operating time of the booster heater. To optimize tank size for capacity and size, the tank should be located so that it receives the hottest water from the heating circuit and the coldest water from the chilled water circuit. This same location will also be desirable from the hydraulic standpoint, since it will minimize pressure in the storage system. In multiple tank installations, series piping of the tanks will decrease balance problems.

Section 4. OTHER TECHNICAL GUIDELINES AND MANDATORY REQUIREMENTS FOR ENERGY CONSERVATION

3.4.1 ECONOMY/ENTHALPY CYCLE. Figure 3-22 shows the regions for enthalpy control. Each HVAC system with cooling capacity greater than 120,000 Btu/hour in buildings not equipped with internal/external zone heat recovery equipment shall be designed to use maximum outdoor air for cooling whenever cooling is needed at an outdoor condition such that:

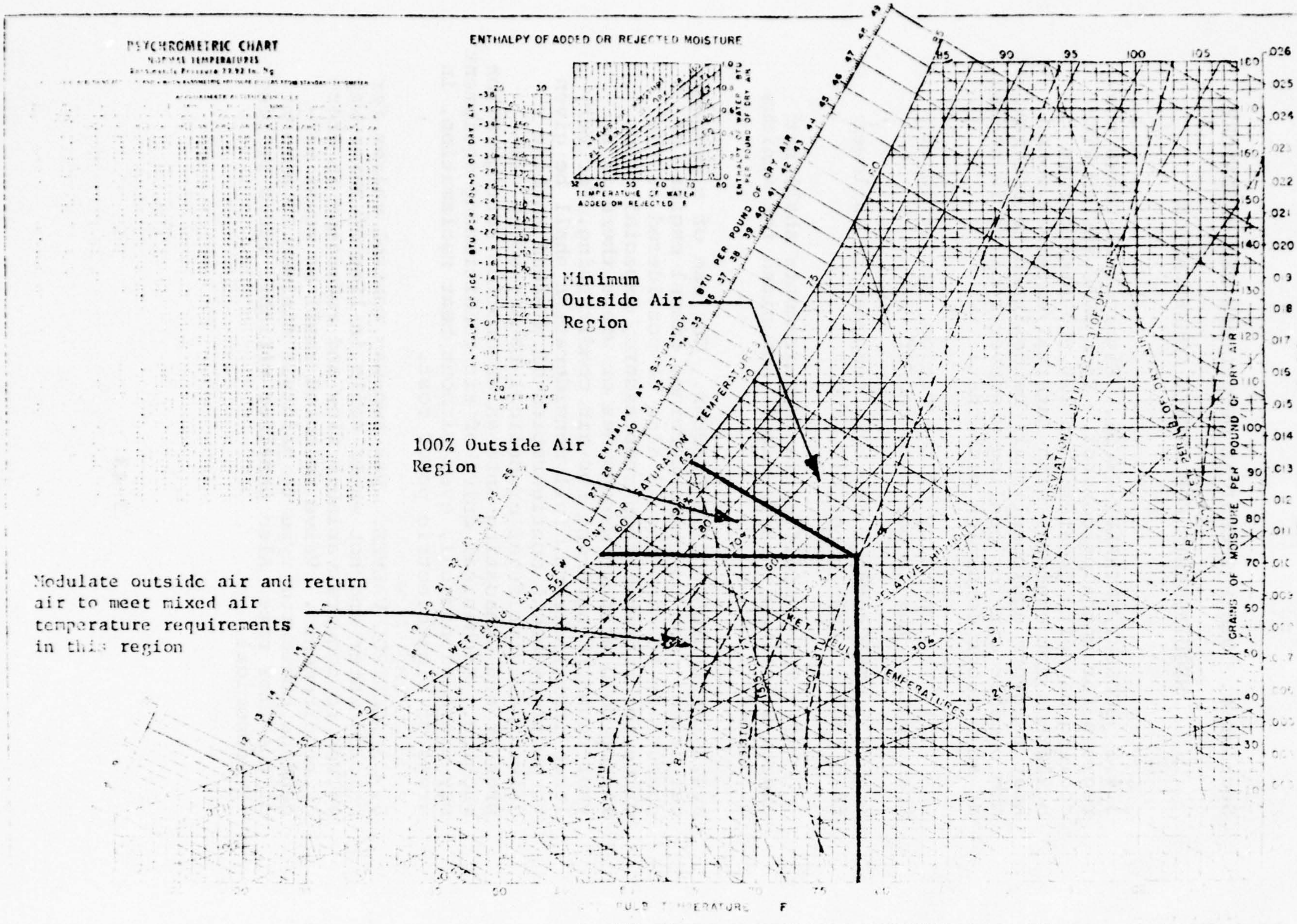
(1) The enthalpy of the outdoor air is lower than that of the indoor air, and/or

(2) The outdoor dry bulb temperature is lower than that of the indoor air, and

(3) The humidification requirements shall not exceed 2.5 times that required when sized for minimum outside air.

3.4.2 MECHANICAL DRIVE SYSTEMS. The use of a mechanical drive, such as steam turbine, diesel engine, or combustion turbine should also be considered as the drive for refrigeration compressors, especially for larger cold storage warehouses or where there is a year-round requirement for air conditioning. For very large installations, full consideration shall be given to a "piggy-back" configuration of a steam turbine driving a centrifugal or helical rotary-screw compressor and exhausting into an absorption refrigeration machine. Mechanical drive of air conditioning equipment may prove economical, even without heat reclamation, in areas of high electric power cost.

3.4.3 CONTROL VALVES. Use two-way control valves for chilled water and hot water coils in lieu of three-way valves to acquire variable flow and reduction in energy requirements. Valve selected shall be equal percentage contoured type to maintain minimum 25 percent of the flow rate. Also consider variable speed pumping if economical.



- -22 REGIONS FOR ENTHALPY CONTROL

3.4.4 PUMPING. Use primary-secondary pumping if it can justify energy savings in lieu of main or primary pumping only. The aim of primary-secondary distribution is:

(1) To isolate secondary circuit from the primary circuit and hence minimize the flow balance problem.

(2) Reduction in overall pump power since each secondary pump circuit is pumped in isolation and only to its own need.

(3) Reduced and diversified flow rate in the primary distribution.

(4) Use of two-way valves in secondary distribution terminal control.

3.4.5 PREHEATING DOMESTIC HOT WATER. Consider preheating domestic hot water with the recovered heat in system that incorporate heat recovery techniques.

3.4.6 CASCADE REFRIGERATION SYSTEM. Consider the use of cascade refrigeration system in lieu of the double-bundle machines if economically justified. It will be possible to get higher water temperature with this system.

3.4.7 SERIES FLOW THROUGH CHILLERS. Consider series flow in lieu of parallel flow in chillers if the overall kilowatt/ton is less. Also, for "piggy-back" configuration series flow may be beneficial to give low energy requirements, with the water to be cooled and coming from the building first entering the absorption unit and then into the turbine driven unit.

3.4.8 HEAT RECOVERY BOILERS. Consider the use of waste heat recovery boilers in conjunction with incinerators.

3.4.9 SPLIT SYSTEM. Split system unitary air conditioning assemblies of the RCU-A-C and RCU-A-CB types having capacities of 60,000 Btuh and less shall have a Btuh/watt ratio of not less than 7.5 based on the condensing unit and coil only. This ratio shall be

established for both types of assemblies from the capacity and power ratings listed for RCU-A-C assemblies in the ARI publication "Directory of Certified Unitary Air conditioners" (latest edition). In determining the ratio for a RCU-A-CB assembly, when the condensing unit is listed under RCU-A-C assemblies with different coils, the condenser coil assembly with the highest Btuh/watt ratio shall be used to determine the acceptability of the RCU-A-CB assembly. In cases where the condensing unit used with a RCU-A-CB assembly is not listed as part of RCU-A-C assembly, the Btuh/watt ratio, based on the information listed for the RCU-A-CB assembly shall not be less than 6.5.

3.4.10 WINDOW UNITS. When room (window) air conditioning units are used, they shall produce not less than 8.5 Btuh per watt input for 120 volts and not less than 8.0 Btuh per watt input for 230 volt units. In order to establish these ratings, the Association of Home Appliance Manufacturers' publication "Directory of Certified Room Air Conditioners" (latest edition) shall be the sole determination. Energy rates for through-the-wall units shall be as specified in Fed. Spec. 00-A-372. All future replacements of room units shall conform to these requirements.

3.4.11 AIR CONDITIONING SYSTEMS. Design air conditioning systems so that all return air passes through louvers in lighting fixtures to prevent lighting and ballast heat from entering the occupied space. Because this method eliminates the lighting heat at the source, it is possible to use smaller air handlers, coils, and ducts since the room load has been lowered. Use this warm air as reheat in air conditioning systems. See paragraph 3.3.3.

3.4.12 SENSING UNIT. Use an outside temperature sensing unit to modulate temperature of hot water heating systems by increasing water temperature as outside air temperature drops and decreasing water temperature as outside air temperature rises. When fan coil units are used to provide both heating and air conditioning, the hot water should be modulated down to a maximum temperature of 75°F. when the outside temperature is 60°F.

3.4.13 SHUT-OFF. Provide a positive shut-off of heating systems when outside air temperature reaches 65°F. In well insulated buildings, cut-off can occur at 60°F.

3.4.14 PROGRAMMED CONTROLS. Use programmed controls through clocks or other systems for night, weekend, and holiday temperature set back (or cut-off) to reduce air conditioning and heating loads. Normally, air conditioning for personnel comfort will be cut off during unoccupied hours and heating reduced by 10°F. to 15°F. depending upon equipment capacity, pick-up limitations, and if no additional energy is consumed.

3.4.15 WINTER AIR CONDITIONING. Use air cooled condensers or cooling towers with indoor sumps to eliminate the need to heat cooling tower basins where air conditioning is required in below freezing weather.

3.4.16 CONDENSER WATER TEMPERATURE. Condenser water temperature for the refrigeration machine (chiller) shall be as low as the ambient temperature will permit but not below the minimum temperature recommended by the chiller manufacturer. This will reduce the kilowatt/ton of refrigeration. Also, if possible, consider varying the condenser water temperature with respect to ambient to lower the energy requirement. Also check with the manufacturer the possibility of obtaining free cooling, i.e., chilled water without running the compressor (thermocycle or free cooling principle). Thermocycle or free cooling provides up to 30 to 40 percent of total chiller capacity by utilizing the cold from outdoor air to get chilled water. Cold water from cooling tower flows through the condenser lowering the refrigerant pressure. This causes the refrigerant from the evaporator to flow to the condenser, where it is condensed. The liquid refrigerant drains by gravity. This process is accentuated by a gas by-pass from condenser to evaporator and liquid refrigerant spray pump that sprays the refrigerant from the bottom of the evaporator and over the chilled water tubes. The system's compressor remains idle during the entire process.

3.4.17 INSULATION. Piping and ductwork insulation shall be optimized to minimize the cost of heat gain

or loss when compared with cost of insulation, but in no case should the thickness be less than that specified in NAVFAC specifications.

3.4.18 BUILDING ORIENTATION. Building orientation and configuration shall be selected to minimize infiltration and solar loads.

3.4.19 INDICATING DEVICES. Install meters and gauges on energy sources to each building and separately submeter energy used for space heating, hot water heating, space cooling, lighting and special power. All new buildings shall incorporate indicating devices such as integrated Btu meters, kilowatt-hours meters, flow meters, temperature gauges, pressure gauges, velometers, fuel meters for boilers, smoke density recorder, orsat, CO_2 and O_2 analyzers; gas meters in each system to monitor and evaluate energy performance.

3.4.20 HIGH Δt. High temperature rise or drop is desirable to minimize the flow rate and to conserve fluid transport energy. The following should be used as a minimum: supply air summer =20° Δt, winter =40° Δt, chilled water =20° Δt, and hot water =40° Δt.

$$\text{Frictional Head} \propto (\text{Flow})^2$$

$$\text{Horsepower} \propto (\text{Flow})^3$$

Theoretically, for 25 percent reduction in flow, the frictional head is 56.3 percent and horsepower is 42.2 percent of its original value. Similarly, for 50 percent reduction in flow, the frictional head is 25 percent and horsepower is 12.5 percent of its original value. This means 25 percent and 50 percent reduction in the flow rate saves 57.8 percent and 87.5 percent of energy respectively.

3.4.21 ENERGY UTILIZATION. Specifications should require that efficiency of all major equipment such as boilers, chillers, central air conditioning equipment, fans, water pumps, heat pumps, etc. be certified by manufacturers. Efficiencies should be based on full load, 75 percent and 50 percent operation. The cri-

teria for selection and sizing of equipment shall meet the requirement of ASHRAE Standard 90-P. Certification from nationally recognized programs such as those of AGA, IBR, ABMA, AMCA, ASME, ANSI, ASHRAE, ARI, etc. is required.

3.4.22 CREDIT. A credit for internal heat of light and people shall be taken when sizing the heating equipment for the occupied period.

3.4.23 FOIL LOCATION. To provide the greatest resistance to heat flow downward, use aluminum foil backed insulation, or aluminum foil backed gypsum board facing upward or outward and facing a closed air space.

3.4.24 EVAPORATIVE COOLERS. Use single stage evaporative coolers as precooler for outside air make-up in air conditioning systems in arid zones.

3.4.25 CONDENSERS. Use air cooled condensers in series with cooling towers to minimize equipment sizes and reduce electrical consumption. Use a small cooling tower in series with a large air cooled condenser for peak shaving particularly in arid zones.

3.4.26 REFRIGERATION MACHINES. Consider use of the double effect absorption refrigeration machines instead of single effect. This reduces the steam requirements from 18 lb./hr./ton to about 12 lb./hr./ton.

3.4.26.1 Note: Double effect machine is a proprietary item by the Trane Company, LaCrosse, Wisconsin.

3.4.27 LOW RESISTANCE FILTERS. Use low resistance filters, registers and grilles.

3.4.28 EXHAUST HOODS. Where possible the air supply on exhaust hoods shall be direct to preclude heating and cooling large quantities of fresh make-up air, then exhausting it outside.

3.4.29 VEHICLE TRAFFIC. Revise in-plant vehicle traffic to cut down on door openings.

3.4.30 HEATERS. Locate all heaters clear of obstructions.

3.4.31 STEAM CONDENSATE. Return steam condensate to conserve both energy and water.

3.4.32 VENTILATION IN ATTIC. Provide ventilation in attic spaces between ceiling and roof for family quarters and other similar buildings with attic space.

3.4.33 FUEL SOURCES. Log all fuel sources, their consumption at least on a monthly basis for each department.

3.4.34 AUTOMATION SYSTEM. A centralized automation system shall be considered for HVAC, load shedding, control of electric equipment, etc., where economically justifiable.

3.4.35 CONTROL DEVICES. The use of control devices such as staging controls, industrial grade controllers, static pressure sensors, time based programmers, etc. shall also be considered where applicable.

3.4.36 CONTROLS. Controls system shall be energy efficient with each zone provided with adjustable automatic control device to maintain the design set point. The set point shall be adjustable within 10° deadband to avoid usage of heating or cooling equipment. A 10°F. to 15°F. night setback for winter unoccupied periods shall be employed, provided additional energy is not required to attain the setback temperature.

3.4.37 REHEAT. Recovered energy is desirable for reheat for control of temperature. The reheat use of energy sources other than recovered shall be minimized by limiting the air temperature rise across the reheat coil to about 7-1/2°F. Proper zoning selection must be considered.

3.4.38 EXHAUST AIR. Minimize exhaust air quantities and provide variable speed or inlet vane control on exhaust fans. This is done to minimize exhaust air since all areas such as toilets need no exhaust unless they are occupied. Exhaust fans should be controlled with static pressure controller. Install individual switch for toilet exhaust instead of tying it with lights.

3.4.39 INTEGRATED AIR CONDITIONING AND LIGHTING SYSTEM. With the exception of clean rooms, animal laboratories, and laboratories with toxic, explosive or bacteriological exhaust requirements, all air conditioned spaces where the general lighting level is 2.5 watts per square foot or greater shall have an integrated air conditioning-lighting system. Use heat of light return to reduce air requirements for the space. See paragraph 3.3.3.

3.4.40 LUMINAIRES. Additionally,,the use of air cooled luminaires shall be considered. See paragraph 3.3.3.(1).

3.4.41 SOLAR SCREENING. The use of glass must be carefully controlled, since glass permits the greatest loss of energy per unit surface area of all the building components. All glass facing south, southwest, and west should be protected from summer time solar exposure by architectural shading, tinted glass or solar screening. Solar screening reduces the direct component of the solar heat load. The other portion of solar heat gain is caused by diffused radiation which affects all exposures. Proper design of solar screening includes consideration of latitude, elevation, orientation, percent of glass, heating and cooling loads, cost, obstruction and inconveniences to such activities as window washing. Consider roof overhangs, horizontal and vertical building projections, louvers, reflective glass coating and roof covering, internal shades, venetian blinds, draperies, awnings, eyebrow reveals, or vertical/horizontal fins.

3.4.41.1 OVERHANGS AND PROJECTIONS. Roof overhangs and horizontal projections of reasonable length provide shading to east and west exposure for the entire year and on the south, southeast and southwest exposures during the late spring, summer and early fall. When properly designed they will no longer shade south exposures during the winter heating season when the sun is too low to be intercepted without excessively long projections. See Figure 3-23. For projection length, see ASHRAE Handbook of Fundamentals 1972, Chapter 22, Table 25.

3.4.41.2 VERTICAL PROJECTIONS. Vertical projections, fins or louvers, (horizontal or vertical) are more effective when they are movable and on the outside of the building. They are effective on the east and the west walls. Outside motor operated louvers have been applied successfully for solar control. They also reduce the impact of higher wind velocity and increases the thermal resistance of the outside air film on the wall and the glass. Awnings will be beneficial for some applications such as residential. See Figure 3-23.

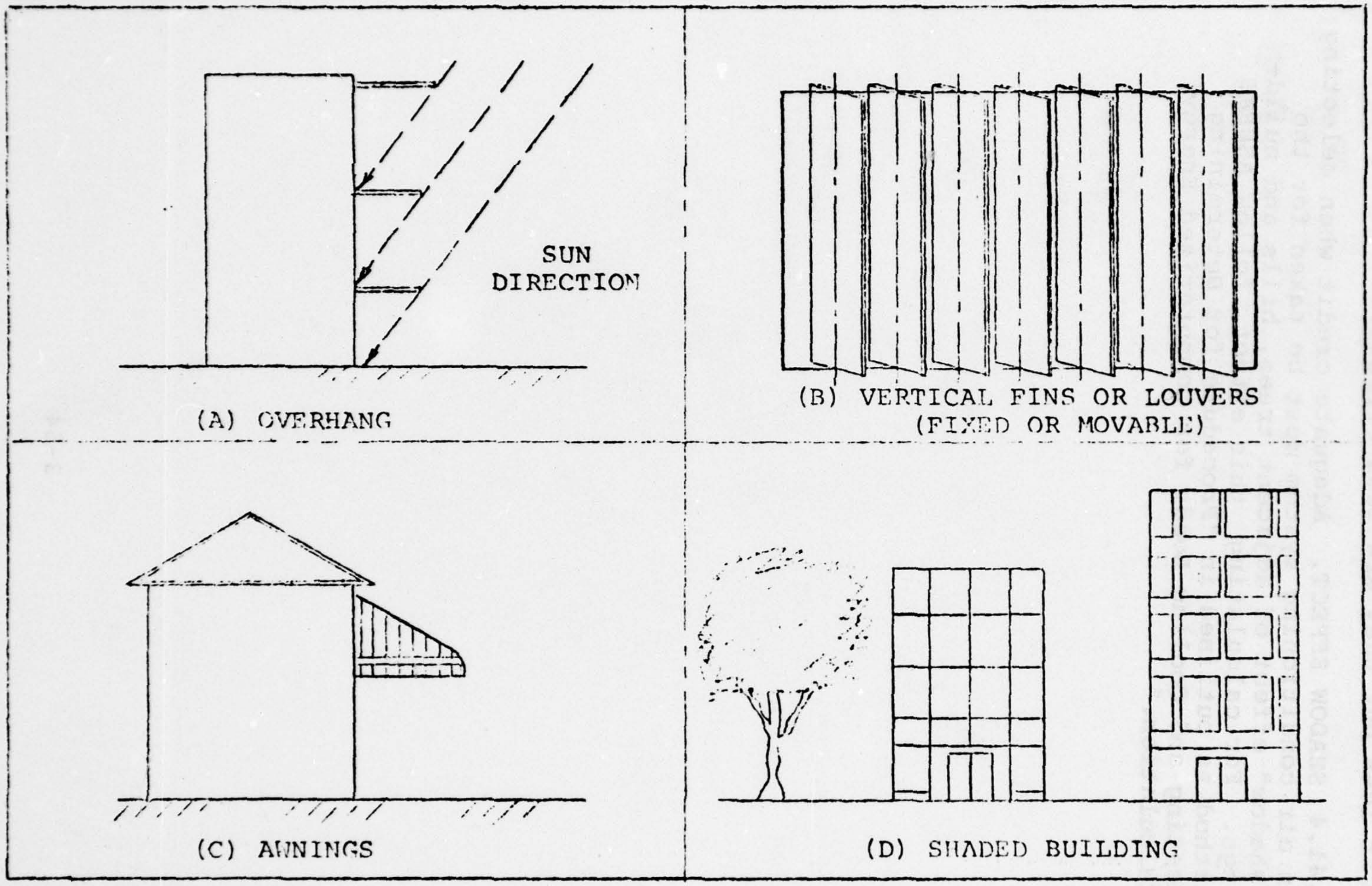


FIGURE 3-23

SOLAR SCREENING

3.4.41.3 INTERNAL SHADING. Internal shading devices cost less but they are less effective.

3.4.41.4 SHADOW EFFECT. Adequate credit when selecting an air conditioning system must be taken for the "shadow" effect of adjacent trees, hills and buildings. For calculating this effect, follow ASHRAE method as outlined in "Procedure for Determining Heating and Cooling Loads for Computerized Energy Calculation."

Section 5. ENERGY SOURCES, SOLID WASTE HEAT RECOVERY AND TOTAL ENERGY SYSTEMS

3.5.1 FUELS. The conventional energy sources for building energy requirements are the fossil fuels: coal, fuel oil and fuel gas. Since the end of World War II, coal has declined steadily as a heating fuel leaving this market almost entirely to oil and gas. By 1985, unless the oil situation worsens or gas continues in short supply, coal should be completely out of the heating picture for heating plants serving individual buildings. However, increased use of coal in large central boiler plants is expected.

3.5.1.1 Coal. Coal lends itself best to a large central heating plant or to a remotely located total energy type of installation. This is because of the large building volumes and adjacent land areas needed for the storage, processing and handling of coal and to house the larger boilers required for its burning. Coal handling operations require conveyors, pulverizers, and additional fans, all of which are noisy and dusty even though some of the operations can be partially enclosed. Also, equipment is required for ash quenching and removal, which consumes large quantities of water, and additional space is required for ash storage as well as remote sites for final ash dumping.

3.5.1.2 Oil. Fuel oil is more convenient to handle than coal. Its storage is simpler and there is no ash disposal problem. The lighter No. 2 fuel oil should be considered for small steam and hot water heating plants and for diesel engine and gas turbine total energy plants. For steam plants having water tube boilers, No. 6 (Bunker C) fuel oil should be considered based on the economics of providing fuel oil storage tank heaters, pump and heater sets and traced and insulated fuel oil lines required for No. 6 oil.

3.5.1.3 Natural Gas. Natural gas is by far the least cumbersome of the fossil fuels. Storage is the problem of the supplier, not the user. Handling is clean and simple. Combustion safeguards are more numerous than in a coal or oil installation, but they have been standardized and are extremely reliable. One of the limitations of natural gas has been its distribution.

The development of various purification and drying processes for natural gas (which is largely methane) has led to its liquification, at low temperatures (-259°F). A mass of gas equivalent to 600 cu. ft. at low pressure can be liquified to 1 cu. ft. of liquid (LNG), and this reduced volume can be shipped by tank trucks to any point within reach of a highway. Natural gases rich in propane and butane, are usually separated and the liquified propane and butane (LPG) can also be shipped by tank trucks. Some LPG and LNG is being imported into the United States via specially modified and refrigerated tanker ships. In accordance with current DoD policy, the use of natural gas is prohibited in boilers of greater than 20,000 lbs/hr capacity.

3.5.1.4 Other Fuels. The feasibility of burning fuels other than fossil fuels should be considered when available, and when proven to be economical. Examples of other fuels that should be considered are wood, paper, sawdust and municipal waste. In a few areas in the world, peat and lignite, which are the early stages in the formation of coal are readily available, but, as can be seen from Table 3-1 their heat (BTU) content is low relative to coal. Wood, of course, had been used as a fuel for centuries before the advent of coal and it is still used in many industries where bark, scrap wood, sawdust, etc. are waste or by-products. Paper, also, is available as waste in many offices, merchandizing and manufacturing operations. As a matter of fact, in many governmental installations tons of paper containing classified information must be incinerated as a routine. Plastics, too, are available as a waste and many can be incinerated. Care must be taken with plastics, however, as many do give off toxic gases. See paragraph 3.5.2 for a discussion of municipal waste as a fuel.

3.5.1.5 Pollution. All combustible fuels are faced with the problem of getting rid of exhaust gases, including products of combustion, some of which may be toxic. Anti-pollution regulations in most states and large cities prohibit the release of such gases without prior treatment to render them harmless. In the case of the fossil fuels, sulphur is the prime polluter causing

the release of sulphur dioxide, a particularly noxious pollutant. The corrective measures are to burn fossil fuels with low sulphur contents, or to install sulphur dioxide removal equipment to treat the exhaust gases. Low-sulphur fossil fuel, which is not in plentiful supply, ranges in price from 50% to 100% higher than ordinary fossil fuels which may range from 3.5% sulphur in coal to as high as 18% in some natural gases. Sulphur removal equipment in a power plant ranges in cost from 25% to 35% of the total installed plant cost.

3.5.1.6 Fuel Selection. The selection of the specific fuel, or fuels, for a specific energy plant is based on economics, availability of fuel, availability of storage space, anti-pollution regulations and safety requirements. The economic factors have been tabulated in Table 3-1 for the Philadelphia area. These may vary for other parts of the country.

3.5.2 SOLID WASTE HEAT RECOVERY. Municipal refuse and industrial waste by-products also are valuable energy sources. In special industries there are many steam boilers fired by solid waste fuels such as bagasse (squeezed sugar cane), coffee hulls, nut shells, wood bark, shavings, and sawdust. Municipal incinerators, which dispose of refuse (solid wastes) while generating steam, are commonplace in Europe and Japan, and are now being installed in Canada and the United States. Two units in the Norfolk Naval Shipyard, Virginia, have been operating successfully since 1967.

3.5.2.1 Waterwall Incinerator-Type Waste Heat Recovery Boilers. They differ very little from stoker-type coal-fired boilers. The furnace volume generally is 15-20% larger for the incinerator boiler due to the greater liberation of gases and to allow for complete combustion of the lighter solids which may be lifted off the grate. Flame temperatures of 2500°F are usual with only 30% excess air. A special type of air-cooled reciprocating grate stoker is required with a steep angle downward in the direction of the feed. The waterwalls and drums of the A-type arrangement are best suited for this type of boiler. Auxiliary fuel oil or gas is necessary to stabilize the flame at low (35% and below) outputs. Except for bulky waste the solid wastes are fed directly into the furnace without processing.

TABLE 3-1

Comparative Energy Costs of Fuel[1] (October 1974)

Fuel	Heat Content, BTU			Cost	Comb.	Rel. Cost
	/Lb.	/Gal.	/Cu.Ft.	$/Unit	Eff.	$/MM BTU
Coal						
Anthracite	13,300					
Semi-anthracite	13,100					
Semi-bituminous	14,100					
Bituminous	13,900			$35[2]	80%	1.57
Sub-Bituminous	9,400					
Lignite	7,100					
Peat	3,600					
Oil						
Crude						
No. 6 (Low Sulfur)		148,000		0.3517	80%	2.97
No. 2		138,500		0.349	80%	3.15
JP Fuel						
Gas						
Natural			1,080	$2.66/1000cf	78%	3.16
LNG						
LPG		91,500				
Waste						
Wood	5,800			$4/tn[4]	60%	0.69
Paper	5,500			$4/tn	60%	0.73
Plastics						
Municipal Waste (IIA[3] Type 1-M)	5,000			$5/tn	60%	1.00

1. For the Philadelphia Area.
2. The cost is per ton of coal.
3. Incinerator Institute of America.
4. The cost is for collection and preparation (shredding).

3.5.2.2 Refractory-Lined Incinerator With Waste-Heat Boiler. The refractory-lined incinerator furnace requires about 300-500% excess air to help keep the furnace walls cool. Flame temperatures of 1500-1600°F are usual. Small incinerators, up to a capacity of 150 tons of refuse per 24 hours, are refractory-lined circular and generally equipped with stationary grates and rotating stoking arms. Larger refractory incinerators (150 tons per 24 hours and above) are generally rectangular in shape and equipped with traveling, reciprocating or rocking grates. Refractory furnaces are susceptible to clinkering and refractory damage as well as excessive fireside tube corrosion and ash deposits on the boiler tubes. It is desirable to make the material homogeneous by shredding to improve combustion.

3.5.2.3 Solid Waste Boilers With Supplementary Fuel Firing.

(1) Processing. Solid waste boilers are generally designed as multi-fueled boilers capable of burning a wide variety of industrial and municipal wastes. Most of these solid wastes are a heterogeneous mixture of combustibles (paper, wood, plastics) and non-combustibles (tin cans, bottles, metal scrap such as loose-leaf binder rings, spiral springs, paper clips, pins, zippers, buttons, etc.). Separation of the non-combustibles is followed by shredding (cutting) and/or hogging (tearing apart) of the remaining combustibles. Shredding, followed by air classification into a light fraction (fuel) and a heavy fraction (reclaimable metals, etc.), is the usual preparation process prior to incineration.

(2) Existing Boilers. Municipal incinerator/steam plants are commonplace in Europe and Japan. In Germany, especially, where each municipality is responsible for supplying district heating steam as well as electricity, municipal waste is a highly-prized fuel. Incinerator/steam plants are making their appearance in the United States. A municipal unit has been in operation at Oceanside (Long Island), New York since the early 1960's. Two units have been operating in the Norfolk Naval Shipyard, Virginia, since 1967, and two more are presently under construction there.

3.5.3 WASTE HEAT RECOVERY FROM BOILERS, ENGINES AND TURBINES. The heart of a steam generating plant is the steam boiler. Figure 4-1 shows a total energy plant of the steam boiler type but if we neglect the main turbine-generator and the auxiliary turbines, we have an ordinary steam generating plant. In this type of plant the only recoverable heat is in the stack gases, and most of this is used to pre-heat the combustion air and feedwater for the boiler. The steam is delivered for end use through a pressure reducing station rather than through a turbine. Auxiliaries may be electric motor-driven, turbine-driven, or both, in which case it may be possible, with proper controls and disconnects to keep a boiler in operation during an electric power outage.

3.5.3.1 Limitation. There are limitations in recovering heat from boiler stack gases. First, it is important that the stack gases be kept above the dew point (approximately 250°F) to prevent condensation in the stack. Any water contacting the stack gases forms a mild sulphurous or sulphuric acid which is highly corrosive. Often, it is necessary to use expensive, corrosion-resistant materials in the stack gas heat exchangers. Second, stack gases cannot be used to pre-heat fuels. This is a hazardous operation and it is prohibited by all safety codes relating to boilers.

3.5.3.2 Steam Turbines. They provide five sources of recoverable heat: the inlet steam, interstage bleed steam, exhaust steam, gland seal condenser water and bearing cooling water. Inlet steam is usually used to drive auxiliaries and for fuel oil atomization in the boiler. Interstage bleed and exhaust steam is used for No. 6 fuel oil pre-heating in the storage tank, pump and heater set, and in fuel oil line tracing. It can also be used in steam coils for combustion air pre-heating to the boiler, and in steam radiators for space heating. Steam gland seal condenser cooling water and bearing cooling water can be used in hot water radiators for space heating and in heat exchangers to provide hot water service for building use.

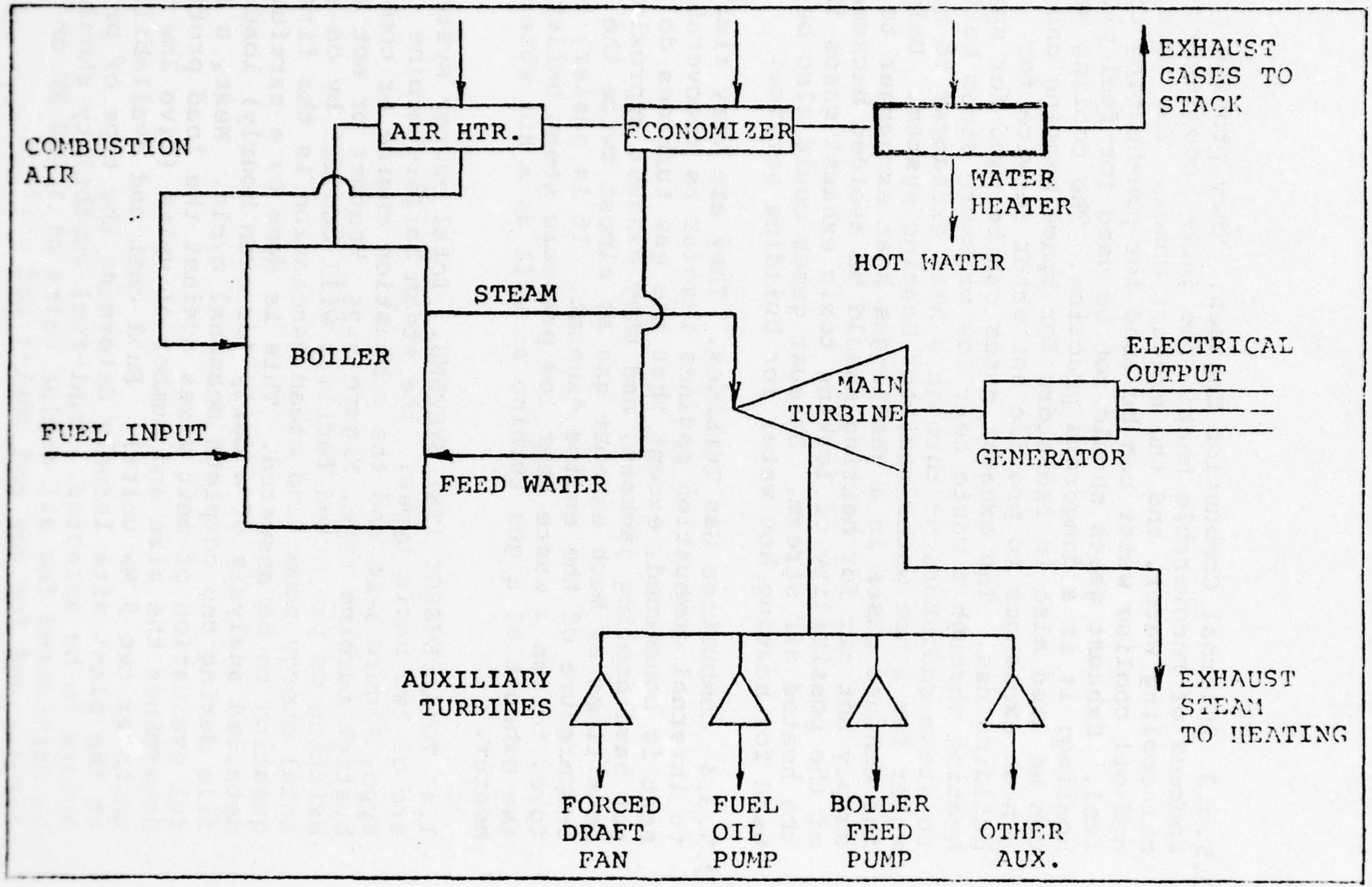


FIGURE 3-24

TOTAL ENERGY SYSTEM USING STEAM BOILER

3.5.3.3 Internal Combustion Engines. They provide three sources of recoverable heat: the jacket cooling water, oil cooling water, and the exhaust gases. The jacket and oil cooling water can be used for pre-heating the fuel. Exhaust gases should not be used for fuel pre-heating; it is a dangerous practice. The cooling water can be used also in radiators for space heating and in a heat exchanger to provide hot water service for building use. The exhaust gases can be used for space heating through a waste heat low pressure steam boiler to steam radiators or through a heat exchanger to heat water for a hot water radiator heating system. Using the exhaust gases in a gas-to-gas heat exchanger to supply hot air for heating should be avoided because of the possibility of leaking toxic exhaust gases into the heated air stream. Exhaust gases could also be used for heating hot water for building service.

3.5.3.4 Combustion Gas Turbines. They are very similar to internal combustion engines insofar as recoverable heat is concerned, except that the gas turbines do not have cooling jackets, and they exhaust approximately four times as much exhaust gas at almost twice the temperature of the engine exhaust. It is easier, therefore, to run a waste heat low pressure steam boiler from the exhaust of a gas turbine as well as a hot water heater.

3.4 TOTAL ENERGY (TE) SYSTEMS. Total energy systems are of two basic types: the steam boiler-turbine type, Figure 3-24, and the combustion engine or combustion turbine type, Figure 3-25. Whether or not an existing or projected facility will benefit by on-site total energy power and steam generation is the first question to be answered. This is done by a careful and detailed analysis of a daily (or even hourly) load profile during one complete seasonal cycle. Next, a careful evaluation of unit sizes against the load profile determines the size and number of units (five 2Mw units or two 5 Mw units). Fuel cost and availability at the plant site largely determine the type of prime movers to be selected. Dual-fuel capability should be considered for all engine units of 1,000 KW or larger, and for gas and coal-fired boilers.

3.5.4.1 Areas for TE Consideration. Total energy systems should be considered and evaluated for all larger buildings or complex of buildings which require both heating and air conditioning. Special consideration should be given to essential facilities such as hospitals, communications centers, and other facilities, which must continue to operate during electric power failures.

3.5.4.2 Steam Boiler-Turbine Type Total Energy Systems. They are generally used where large amounts of steam are needed for heating and/or process requirements. When the heating load is decreased, in the summer, the steam may be used in absorption machines for air conditioning. This sort of piggy-back system is described in Chapter 3-4. In this type of system the main generator is driven by a steam turbine and most, if not all, of the auxiliaries are driven by steam turbines. Most modern industrial and office facilities need precision-controlled frequency and voltage for computers, clocks, and process control. The steam turbine with its excellent regulation, load-following and control characteristics lends itself perfectly to this application. Steam is available at boiler pressure, interstage bleed pressure and turbine exhaust pressure for auxiliary drive and for heating purposes. Further heat recovery can be obtained from the boiler stack gases, turbine gland seal condenser water, and bearing cooling (lube oil cooler) in water.

3.5.4.3 Combustion Engine Type Total Energy Plant. This is more desirable where less of a steam load is required. The engines may be connected to serve as peaking power units or standby emergency units. Another possible arrangement is to connect the engines to a heavy constant load, such as air conditioning, and by quick disconnect couplings be able to switch over to emergency electric power generation in case of a power outage. Dual-fuel supply should be considered using Diesel oil (No. 2) and natural gas. Heat can be recovered from the engine jacket cooling water, bearing (lube oil) cooling water and exhaust gases.

3.5.4.4 Combustion Gas Turbine Plant. They operate with 200% to 400% excess air in order to keep the

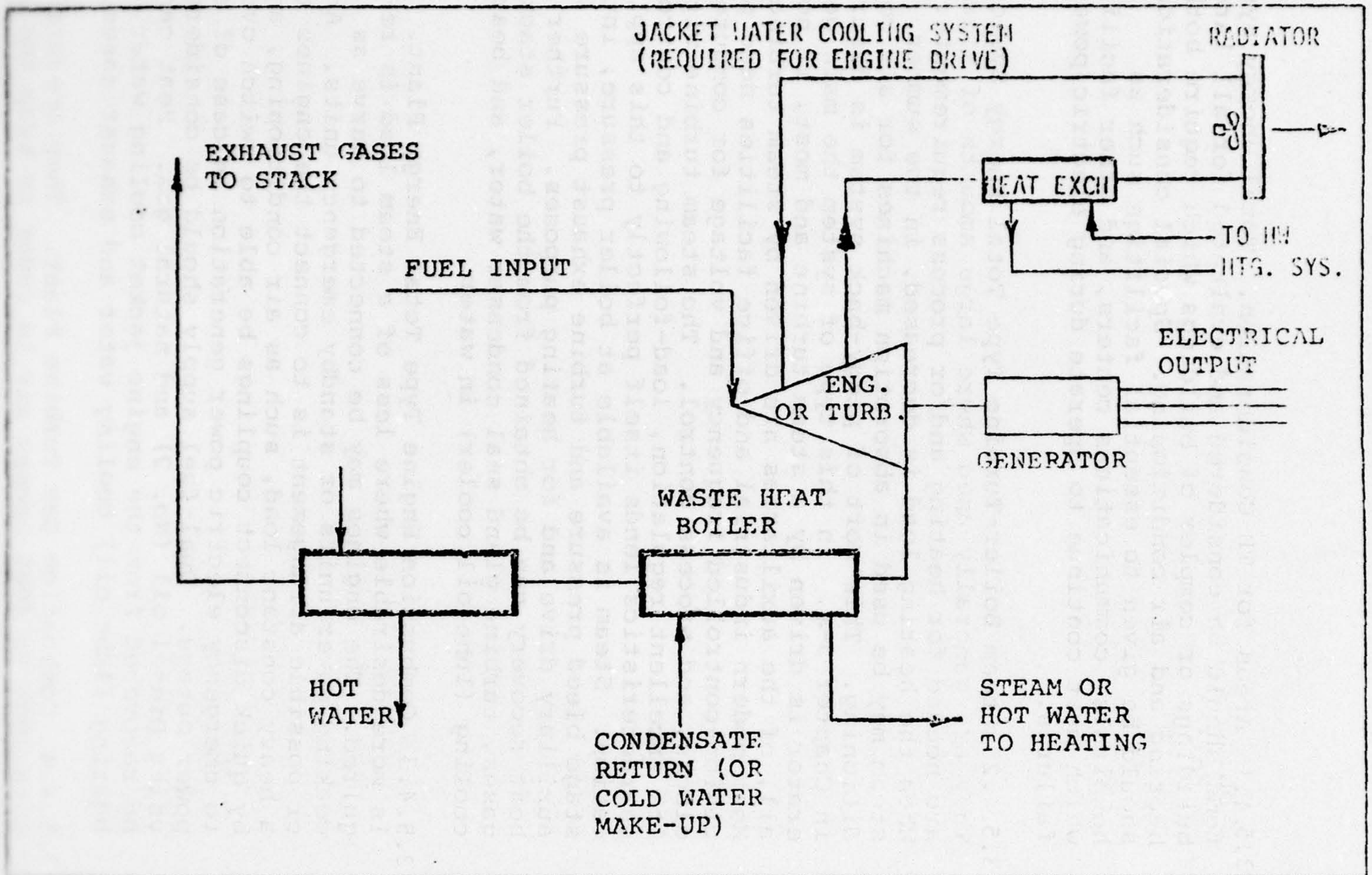


FIGURE 3-25

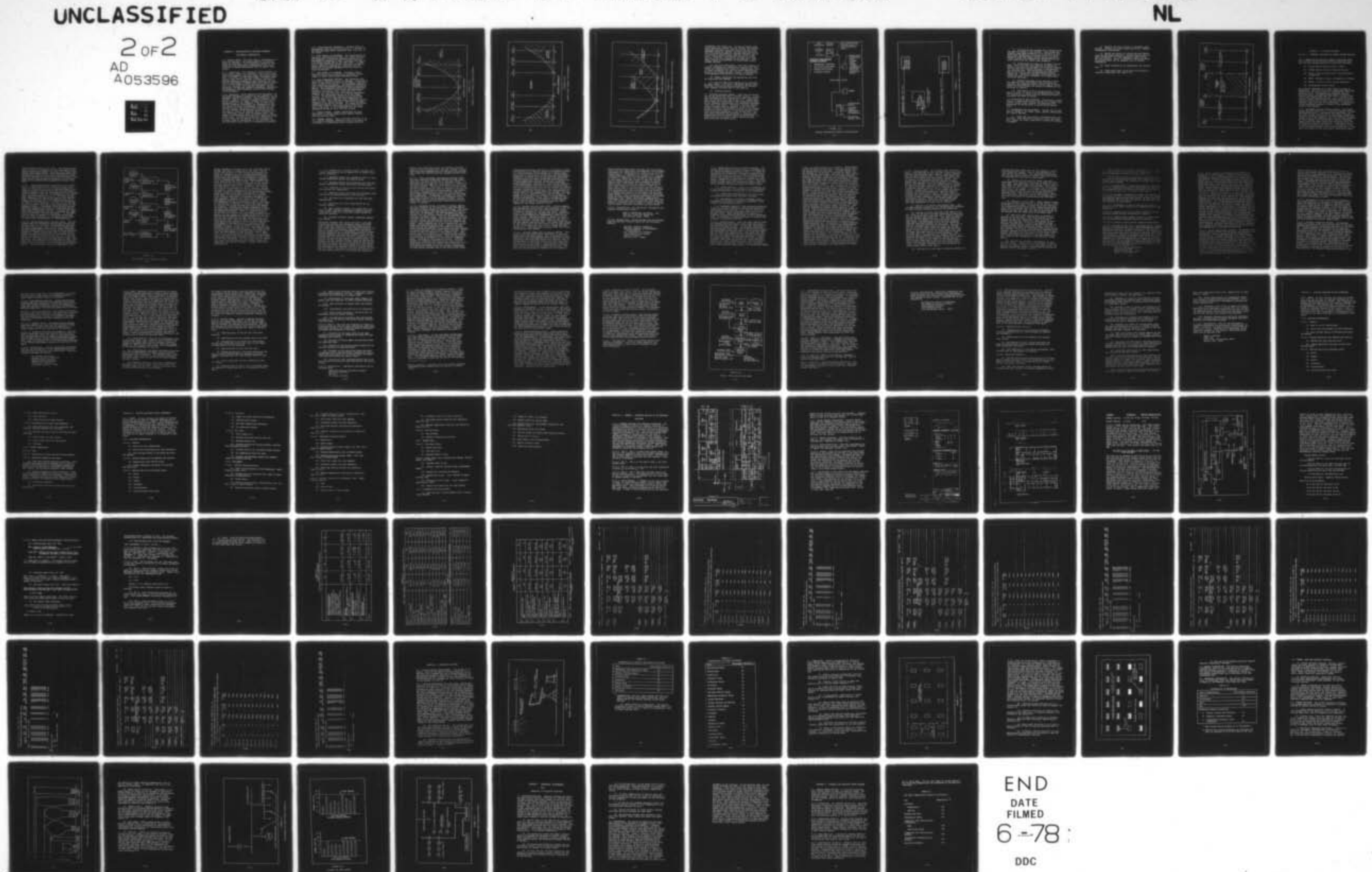
TOTAL ENERGY SYSTEM USING COMBUSTION ENGINE OR TURBINE

mechanical parts of the turbine cool and to insure complete combustion within the turbine. Exhaust temperatures are on the order of 1,000°F. With such volumes of air at such high temperatures, a waste heat recovery boiler can be placed in the system to generate low pressure steam. The pressure and quantity of steam available is dependent upon the size of the gas turbine and the amount of heat available in the exhaust gases. Gas turbines may be arranged and operated in very much the same way combustion engines are arranged and operated. The major difference is that gas turbines are practically instant-starting with no warm-up period required. Heat is recoverable from the bearing (lube oil) cooling water and the exhaust gases. The gas turbine can be made to operate with practically any liquid or gaseous fossil fuel available, which gives it a multi-fuel capability.

AD-A053 596 KLING-LINDQUIST INC PHILADELPHIA PA F/G 13/13
INTERIM DESIGN CRITERIA, TECHNICAL GUIDELINES FOR ENERGY CONSER--ETC(U)
JAN 75 K N PATEL, H C SHANER, P J SARACENI N00025-74-C-0022

UNCLASSIFIED NL

2 OF 2
AD
A053596



END
DATE
FILMED
6-78
DDC

CHAPTER 4. MODIFICATION OF EXISTING CONTROLS FOR ENERGY CONSERVATION

4.1 INITIAL INPUT. The first step in modification of existing controls is to obtain specific information about the building. This information should be tabulated and then analyzed for modification and incorporation of energy conservation devices and/or techniques.

4.1.1 Tabulation. The tabulation should include: all fans (supply, return air, exhaust); the central plant (heating equipment - boilers, pumps; and cooling equipment - chillers, chilled water pumps, condenser pumps, cooling tower fans); lighting (interior, exterior - parking lighting, display or sign lighting); and all other miscellaneous equipment which uses energy (domestic hot water heaters, data processing areas, elevators, air curtains, snow melting equipment, medical equipment, kitchen and cafeteria equipment, manufacturing equipment, shop equipment, and any other energy using equipment).

4.1.2 Operation. After tabulating the equipment, the pertinent information relating to the operation of the equipment should be included. This information should include: type of starting or stopping (manual, automatic, interlock, or other); whether the run time is determined by a 5 day schedule, 6 day or other with holiday schedules considered; the horsepower of each fan, motor, or piece of equipment involved; air temperature control set points; water temperature control set points; steam pressure control set points; the type of control of lighting (wall switching, control switching, on-off from the breaker panel; the number of watts/square foot in office areas, hallways, other areas. Old control drawings or schedules do not always yield the best source for this information. A visual check of information is the desirable basis for data which can be used in a meaningful evaluation.

4.1.3 Miscellaneous Information. Another piece of supplemental data which can be useful is a history of the previous years bills (electric, gas, fuel oil, or any other).

4.2 TIME CONTROL OF EQUIPMENT. The incorporation of automatic time control for fans, etc. whose starting and stopping are presently manually controlled can reasonably be expected to save 15 minutes per day, or a 3% energy savings due to run time alone. In addition to the electrical saving, there will be supplemental savings in reduced run time which can be reflected as extended equipment life and less frequent maintenance.

4.3 TIME CONTROL OF LIGHTING. By adding timers, lighting levels can be reduced in hallways, toilet rooms, or other areas during unoccupied times.

4.4 SPACE THERMOSTAT SETTINGS. The thermostat settings are an important point to consider. A setting of 68°F. in the winter and 78°F in the summer should provide acceptable environment. The changeover should be made in the intermediate seasons during an unoccupied period. The changeover should not require additional heating or cooling to obtain these new temperature settings, see Figures 4-1A, 4-1B, and 4-1C. For example, on a fall day when the building temperature is 74°F. the thermostats should be at the summer setting. If during that evening the building temperature falls to a night set back temperature of 60°F. or 65°F. then a daytime space thermostat setting change to 68°F. should be made. This will preclude unnecessary heating or cooling. For larger buildings, which have interior zones that require cooling for most of the year, it is recommended that the space thermostat be set at 78°F. all year around.

4.5 DEMAND CONTROL. Demand controllers are very beneficial in saving owners excess demand charges and high billing rates.

4.6 CENTRAL CONTROL. When a building has most of its air handling equipment located in one or two areas of a building, a centralized control system should be

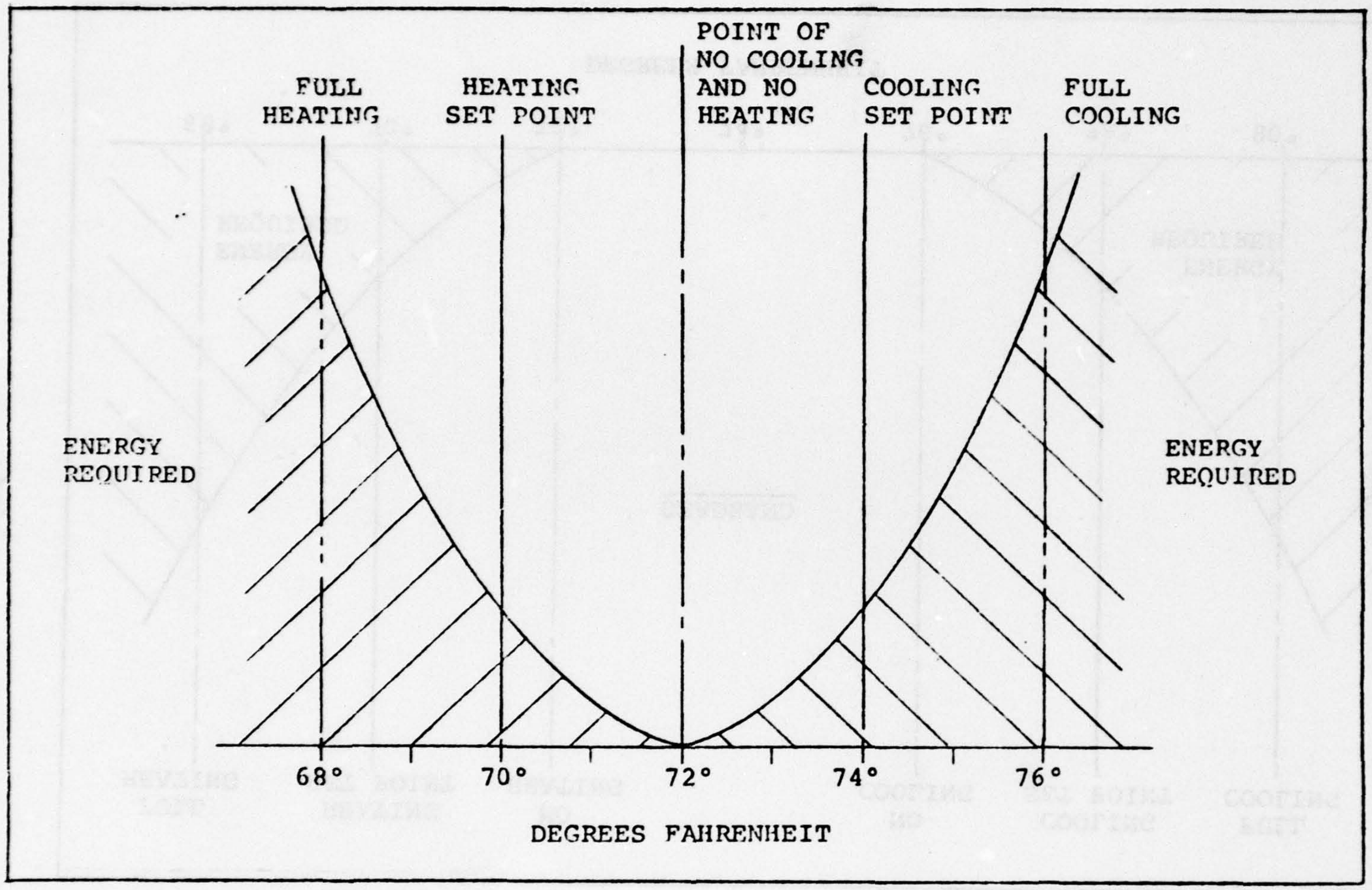


FIGURE 4-1A

ENERGY USING CONTROL WITHOUT DEADBAND

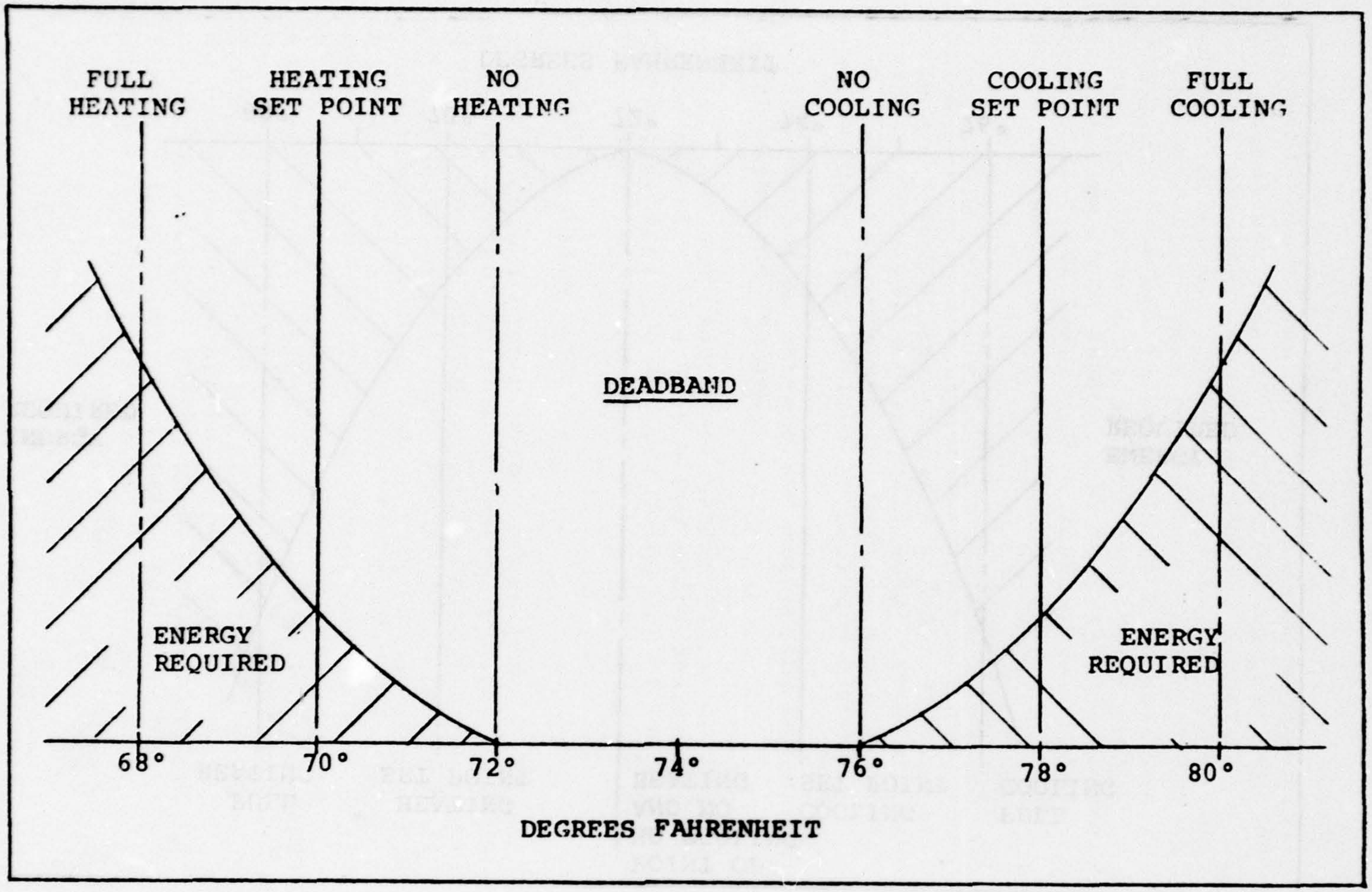


FIGURE 4-1B

ENERGY USING CONTROL WITH DEADBAND

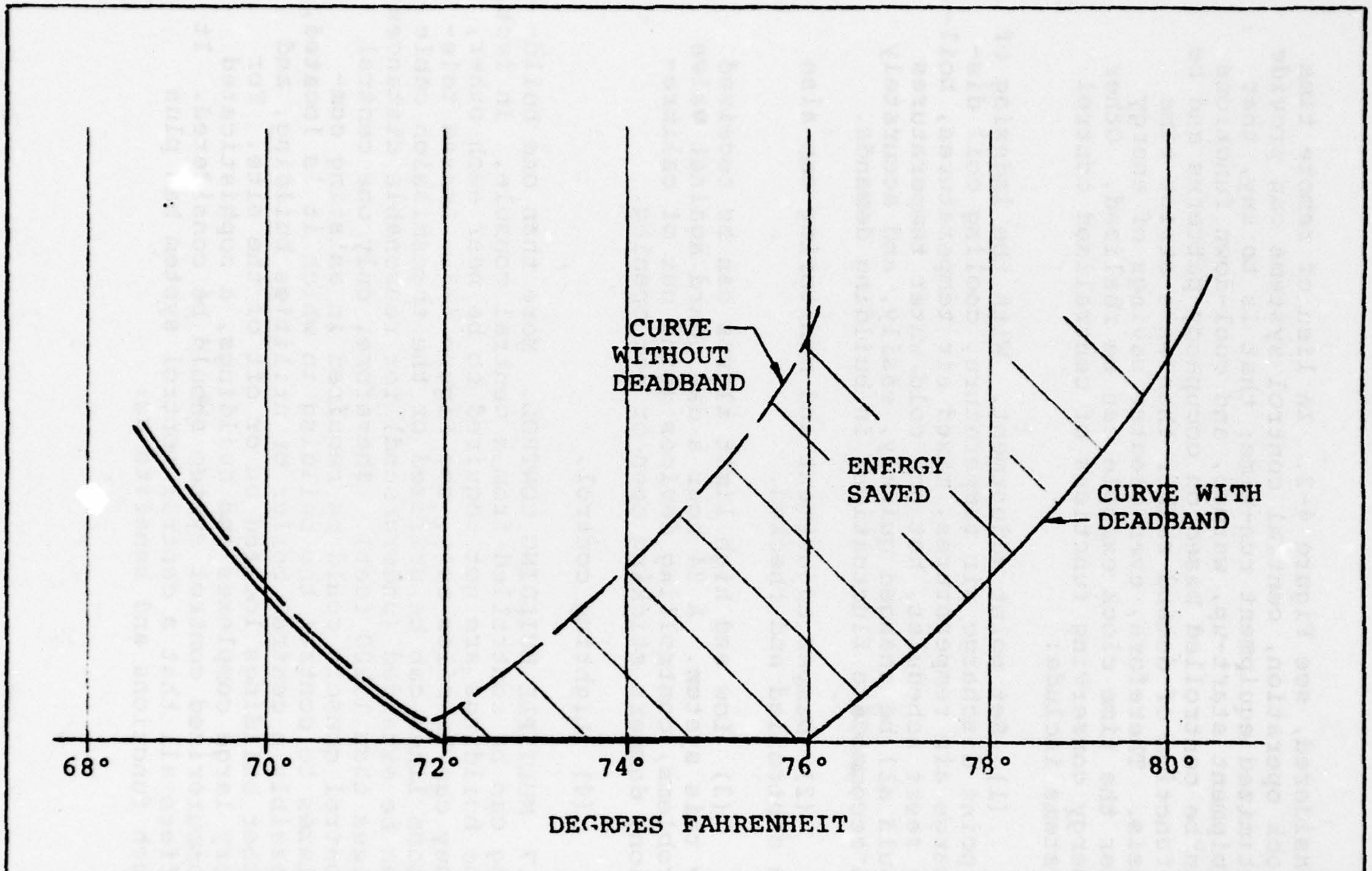


FIGURE 4-1C

COMPOSITE SHOWING ENERGY SAVING USING DEADBAND

considered, see Figure 4-2. In lieu of remote time clock operation, central control systems can provide optimized equipment run-time; that is to say, that equipment start-up, warmup, and cool-down functions can be controlled based on occupancy patterns and be a function of demand rather than on a strict time basis. Therefore, even greater savings of energy over the time clock example can be realized. Other energy conserving functions of centralized control systems include:

(1) Set point adjustment. With the indexing of a point discharge air temperature, cooling coil discharge air temperatures, mixed air temperatures, boiler reset schedules, hot and cold water temperatures could all be changed quickly, easily, and accurately to accommodate fluctuations in building demands.

(2) Damper adjustment and monitoring can also be controlled and checked.

(3) Low and high limit alarms can be received by this system. A 24 hour a day guard against valve problems, controlling devices going out of calibration, dampers sticking open or not opening.

(4) Lighting control.

4.7 MULTIPLE BUILDING CONTROL. More than one building can be controlled from a central console. In fact, the buildings are not required to be near each other, they can be miles away, see Figure 4-3. Leased telephone lines can be utilized or the transmission cable can be extended (underground) for reasonable distances (less than 1,200 feet). Therefore, only one central control console could be required in existing complexes to control the building in which it is located, possibly a central boiler or utilities building, and other buildings located on or off of the site. For very large complexes and buildings, a sophisticated computerized control system should be considered. It offers all that a central control system has plus such functions and benefits as:

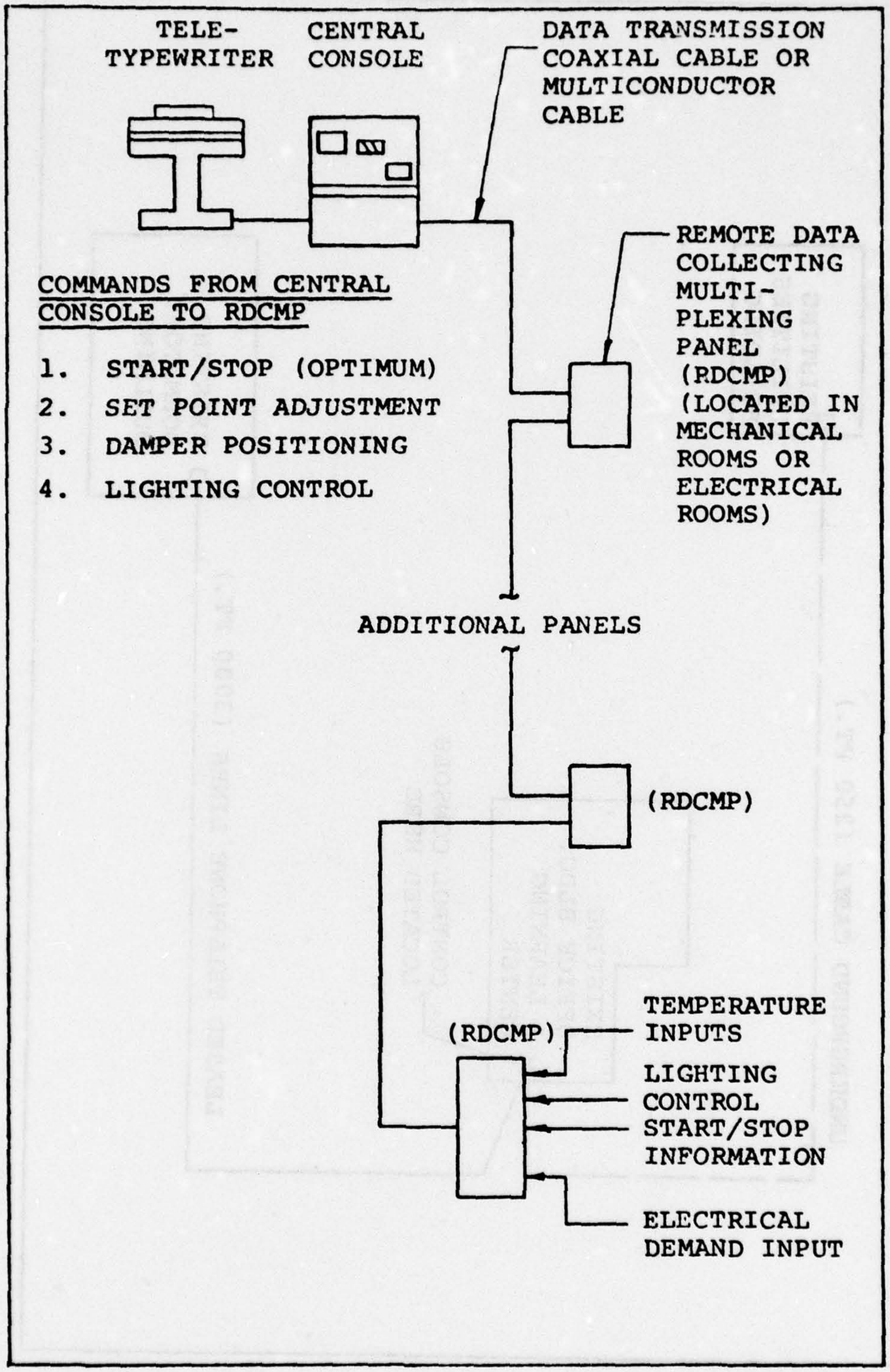


FIGURE 4-2

TYPICAL CENTRALIZED CONTROL SYSTEM LAYOUT

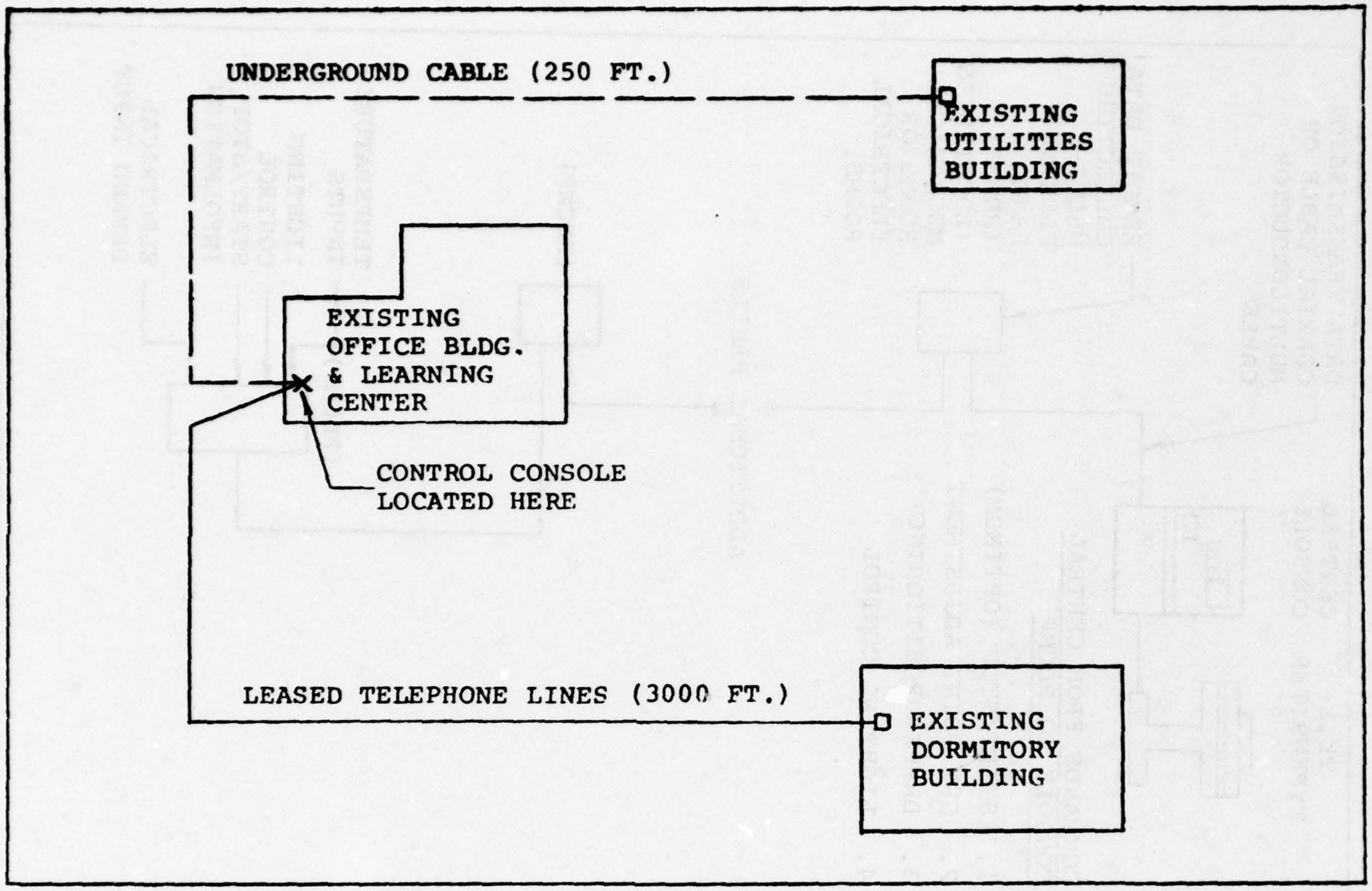


FIGURE 4 -3

TYPICAL MULTI-BUILDING CONTROL FROM A SINGLE CONTROL CONSOLE

(1) Anticipated and automatically controlled by the rate of change in the weather. This allows the normally used reset schedules to be adjusted so that when large temperature variations occur in a short period of time the proper control points can be obtained without over shooting and energy waste which would occur with the normal reset schedule.

(2) Accumulated run-times for equipment can be made. This will allow the operator to review excessive run-times for equipment and possibly reducing the run-times by changing settings or rescheduling the starting time. The accumulated run-time information can also be used for maintenance program scheduling. Regularly scheduled maintenance can increase the life of the equipment, also enable more efficient operation.

(3) Computer programs can be applied to alert the operator when high demand rates are being approached, and immediate action can be taken to avert excess building changes and electrical demand for the building or complex.

(4) Calculation of Btu's being used at a given point in time. If this is an excessive amount, then the systems being served could be checked in order to eliminate the waste of energy.

4.8 EVALUATION OF MODIFICATIONS. Evaluation of local timers, a centralized control system or a computerized control system, must consider the remaining life expectancy of the building in establishing present worth.

4.9 MAINTENANCE AND ADJUSTMENTS. Another way to stop wasting energy is to check, clean, adjust, recalibrate all control devices.

(1) Check the set points on thermostats and controllers. Also check the closing of valves and dampers, inspect for tight close off of valves and leakage of dampers.

(2) Replace the dirty filters in pneumatic thermostats. Replace all poorly operating valves, dampers, thermostats, controllers.

(3) Adjust set points on controllers and thermostats to the proper settings. Install blank covers on space thermostats (so that temperature and settings are not visible). Also, if possible, remove set point adjustments which can be tampered with or replace thermostats.

(4) Check calibration of thermostats and controllers.

(5) Widen dead bands (areas where no heating or cooling is required), see Figure 4-4.

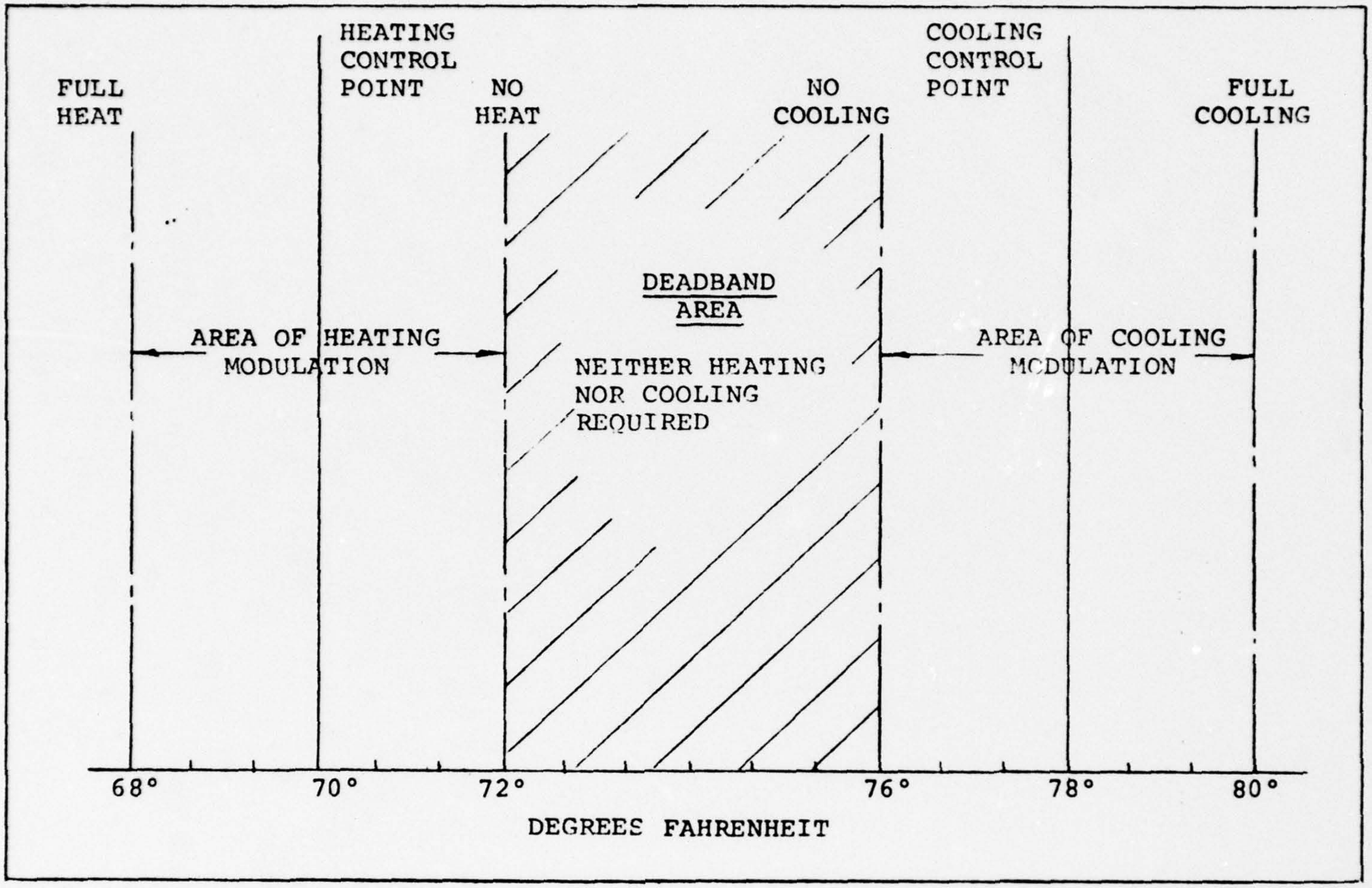


FIGURE 4-4

INTRODUCTION OF WIDE DEADBAND AREA USING
4°F THROTTLING RANGE FOR HEATING AND COOLING

CHAPTER 5. COMPUTER PROGRAMS

Section 1. COMPUTER PROGRAMS FOR ENERGY SYSTEM ANALYSIS

5.1.1 Commercially available computer programs which are suitable for performing building energy use analysis and HVAC system selection include the following:

(A) Energy System Analysis Series (ESA)

(A) AXCESS Energy Analysis Computer Program

(A) ECUBE - Energy Conservation Uitlizing Better Engineering

(B) MACE - McDonnell Annual Consumption of Energy

(B) TRACE - Trane Air Conditioning Economics

(B) Westinghouse Energy Study

The computer programs are grouped above in order of capability. The first three are recommended since they provide hour by hour energy use estimates for 8760 hours per year. A supplementary computer program, Heating Cooling Calculations (HCC-III), is also included in the program descriptions. It is a heating and cooling design load program and lends itself to energy analysis only by way of peak load definition which is required input for some of the programs. A description of the available programs is given in the following pages of the section.

5.1.2 THE ENERGY SYSTEM ANALYSIS SERIES. The Energy System Analysis Series is a library of computer programs developed by Ross F. Meriwether and Associates, Inc. for hour-by-hour calculation of the annnual energy consumption of various types of air-side systems and mechanical plants, for applying local utility rate schedules to these demands and consumptions, and for combining these costs with other owning and operating costs for year-by-year cashflow projections. Each major step in a complete energy system analysis is handled by a different program, thereby permitting the engineer to evaluate the results of one part before finalizing inputs

and proceeding with the next part. The Energy System Analysis Series is designed to calculate monthly and annual energy requirements and costs, not design point heating and cooling loads. These programs begin with design point loads for the overall building or major building sections and distribute them throughout a full year cycle of the building's operation. The six programs in the library are explained as follows: (Fig. 5-1).

5.1.2.1 Energy Requirements Input Data Check (ERCK). This is a preliminary, free-standing program which reads the input data for the various buildings or sections to be run in the building energy requirements estimate program (ERE) and expresses them on a unitized basis to permit a check of the magnitude of the potential loads and system capacities. The input to the ERCK program is the same as the data for the ERE program. The output of the ERCK program begins with a display of the input data. It affords an opportunity to check all the values that will be used in the computer and correct any errors that could cause the ERE program to abort. Percentage variation profiles and operating schedules are shown on an expanded hourly basis for checking and reference. The unitized input data follows and allows the user to compare his input loads to reference "rule-of-the-thumb". It also permits the user to compare his installed heating and cooling system capacities to the design point loads to verify that the equipment is sized adequately.

5.1.2.2 Energy Requirements Estimate (ERE). The ERE program uses the calculated design point heating and cooling loads as a reference and determines the hourly loads using actual values of dry bulb temperature, dew point temperature, cloud cover, solar radiation, and percentage profiles for various building operating schedules. Hourly weather data that is used in the energy requirements calculations is obtained from the National Climatic Center (see Section 5.1.2.8 for address) and consists of 8760 hourly values of dry bulb, dew point, and cloud cover for some typical year. Programs have been developed for selecting and preparing this weather data for use in the Energy System Analysis Series. Solar radiation tables as published in the

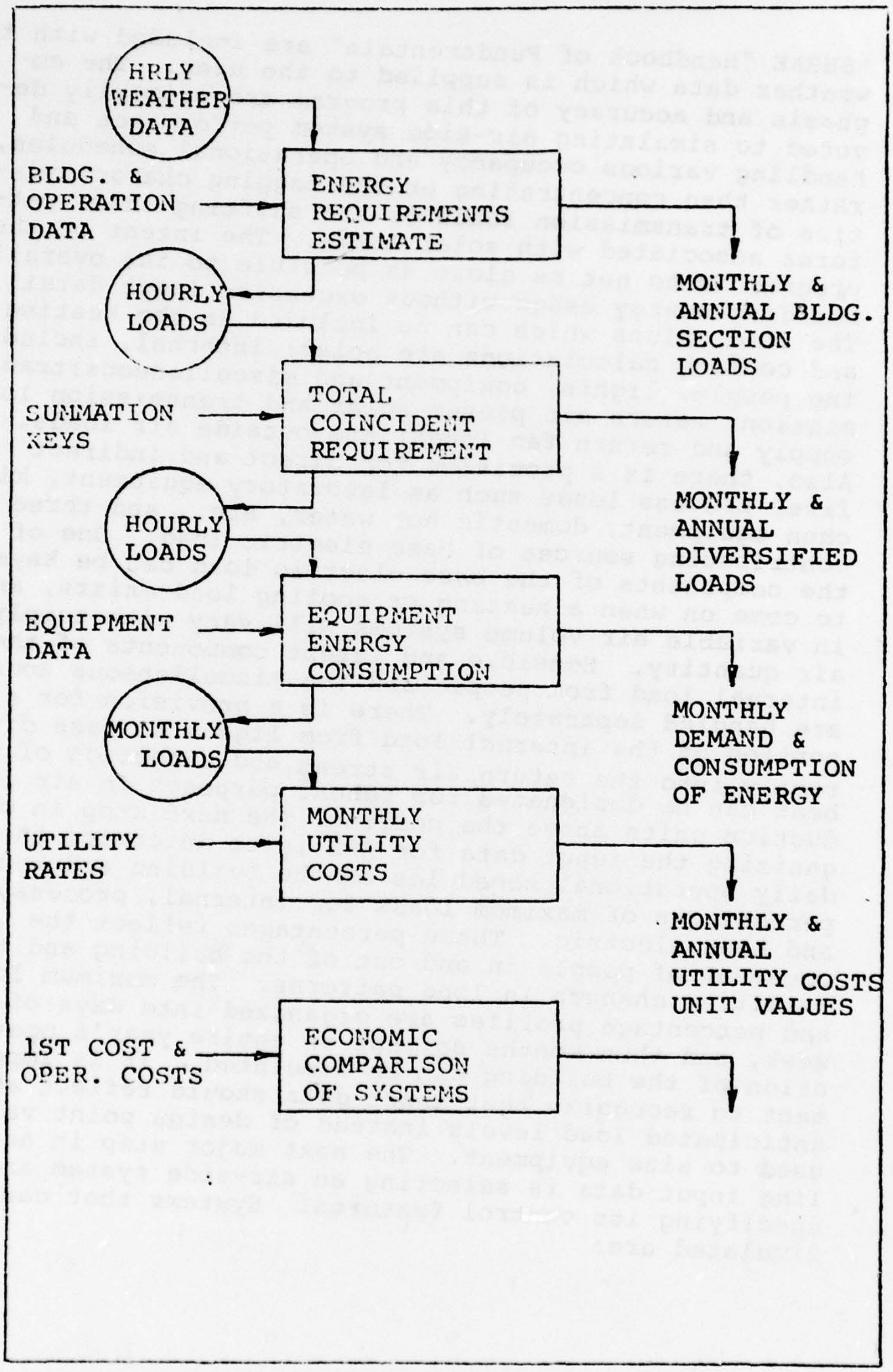


FIGURE 5-1

THE ENERGY SYSTEM ANALYSIS SERIES

ASHRAE "Handbook of Fundamentals" are included with the weather data which is supplied to the user. The emphasis and accuracy of this program are primarily devoted to simulating air-side system performance and handling various occupancy and operational schedules, rather than concentrating on the lagging characteristics of transmission loads or the shifting shade patterns associated with solar loads. The intent of the program is to get as close as possible to the overall building energy usage without excessive input detail. The load values which can be included in the heating and cooling calculations are solar; internal, including people, lights, equipment and miscellaneous; transmission; return air plenum solar and transmission loads; supply and return fan loads; and outside air loads. Also, there is a provision for direct and indirect fired process loads such as laboratory equipment, kitchen equipment, domestic hot water, etc., and three contributing sources of base electric load. One of the components of the base electric load can be keyed to come on when a heating or cooling load exists, and in variable air volume systems will vary with supply air quantity. Sensible and latent components of the internal load from people and the miscellaneous source are handled separately. There is a provision for a portion of the internal load from lights to pass directly into the return air stream, and a portion of this heat can be designated for reheat purposes in air induction units above the ceiling. The next step in organizing the input data for ERE is to determine the daily operational schedules of the building and hourly percentages of maximum loads for internal, process, and base electric. These percentages reflect the movement of people in and out of the building and the resulting changes in load patterns. The maximum loads and percentage profiles are organized into days of the week, and then months so that an entire year's operation of the building can be simulated. It is important to recognize that input data should reflect actual anticipated load levels instead of design point values used to size equipment. The next major step in assembling input data is selecting an air-side system and specifying its control features. Systems that can be simulated are:

(1) Single duct, constant volume, variable discharge temperatures set by demand with no excess cooling or reheating.

(2) Terminal reheat with scheduled cold coil discharge temperature during the cooling cycle.

(3) Terminal reheat with scheduled cold coil discharge temperature during cooling or heating cycles.

(4) Induction or fan-coil type system with scheduled primary air temperature.

(5) Terminal reheat with cold coil discharge temperature set by maximum demand of any section.

(6) Dual-duct with scheduled hot and cold deck temperatures.

(7) Dual-duct with deck temperatures set by greatest demand.

(8) Split conduit system with single duct, constant volume; variable temperature system to offset transmission loads and a variable volume system for solar and internal.

(9) Standard variable volume, scheduled temperature system.

Additional features that can be utilized in the ERE program are outside air economizer cycle, cold deck reset schedules according to ambient temperature or time clock, heat recovery devices operating between return and outside airstreams, supplemental perimeter heating systems that are independent of central system, holiday scheduling for accurate representation of operating schedules, distinction between on and off peak time periods for electrical service, capability to interrupt gas service and switch to auxiliary fuel, calculation of heat storage effects caused by shutoff and setback, and the ability to print selected days during the year to observe the hourly behavior of the system. The output printout includes monthly and annual peaks and consumptions for heating, cooling, process and base electric loads. The hours of heating and cooling system operation are shown for each month and annually.

Data is also given for minimum and maximum room temperature that occurred during the year, number of hours capacities were exceeded and unitized peak and consumption values for heating cooling, process and base electric.

5.1.2.3 Total Coincident Requirements Program (TCR). The input consists of multiple ERE hourly load output tapes plus the data called for on the input forms. A multiplier can be used with each building or section if ERE runs have been made on a unit basis, such as in an apartment complex. The output of the TCR program shows the diversified peaks and time of occurance, as well as the sum of the individual building peaks. The monthly and annual consumptions are shown for the combined plant loads, and unitized values are printed for peaks and consumptions. If desired, a printout is given for the number of hours at ten percent increments of assumed peak loads to aid in equipment sizing. Coincidental peak steam and electrical loads can also be obtained, if desired.

5.1.2.4 Equipment Energy Consumption Program (EEC/B). The input consists of an hourly load tape from ERE or TCR plus the data entered on the input forms. The rated capacities and part load performance are required for each piece of equipment, and this equipment is then organized into the various systems and the appropriate accessory equipment loads. Typical systems that can be simulated are total energy with heat recovery, gas heating and cooling, gas heating and electric cooling, all electric, and purchased chilled water and steam or hot water. Energy sources may be gas, electricity, or any other fuel specified by the user. Chillers in each system can be any combination of direct or indirect-fired absorption machines, steam-turbine driven machines, gas engine chillers, or electric motor chillers. Boilers can be gas or electric or any special fuel. Generator sets can be driven by reciprocating gas engines, gas turbines, or steam turbines. Heat recovery can be utilized from prime movers or from chiller condenser water. Features of this program include: different methods of scheduling machines on the line; various sequencing schedules for accessories; separation of on-peak electrical usage for special rates; flexibility in handling recoverable heat and heating requirements in each system; multiple ERE or TCR hourly load tapes

representing different sections in a building or different buildings in a complex, premitting separate systems in a single complex to be grouped on a single meter; provision for a multiplier to be used with any system; capability to adjust chiller and generator performance characteristics and their associated accessories for ambient temperature effects; simulation of cooling tower performance with constant or variable condenser water temperature; provision to limit chiller capacity in selected months; provision to limit electrical demand in selected months; and improve methods of handling accessory equipment scheduling. The output information includes monthly and annual peaks and consumptions for energy input to the equipment in each system. Unitized values are also shown for comparison and checking. The number of operating hours is shown for each machine monthly and annually. Other useful information shown in the printout includes utilization of recoverable heat, loads in excess of equipment capacity, and a summary of the energy usage by source.

5.1.2.5 Monthly Utility Costs (MUC). Utility demand and consumption values from a tape generated in the EEC program are input to the MUC along with input cards containing the specific utility rate steps. Alternatively, the demands and consumptions can be entered on cards and the program run independently from any previous program. The MUC program is capable of calculating demand and consumption charges for gas service, electric service, chilled water, steam or hot water, and any special auxiliary fuel. The output shows monthly and annual costs for each energy form in each system as well as average costs per unit of energy and per square foot. The total yearly energy costs (all forms) are shown for each system.

5.1.2.6 Economic Comparison of Systems (ECS/B). This program uses the energy costs determined in MUC plus other annual operating costs, such as maintenance and operating labor, and combines these costs with initial investment and associated owning cost factors, such as depreciation, to find the annual cash flow each year for the life of the system. Annual utility costs and other operating costs can be independently escalated each year by a percentage supplied by the user. The initial investment may be divided into two segments

with different depreciation periods, and a provision exists for four additional reinvestments (for equipment replacement or staged projects) which can be on a recurring basis. In addition to straight cash flow and a discounted cash flow for each system on an independent basis, a comparison can be made of each system to the lowest first cost system to show the net savings of reduced operating costs compared to higher owning costs. The output for each system shows the year-by-year and total period values of debt balance, debt interest, equity balance, equity interest, total owning cost, total operating cost, total owning plus operating cost, and equivalent current dollars. If a comparative analysis is performed, the printout shows annual and total values of owning and operating costs savings, total owning and operating cost savings before principal payment difference, depreciation difference, etc., total owning and operating cost savings. The discounted rate of return on total gross investment difference and the number of years to recover initial gross investment difference are also shown.

5.1.2.7 Availability. For additional information and program availability contact:

Ross F. Meriwether and Assoc., Inc.
1600 N.E. Loop 410, Suite 241
San Antonio, Texas 78209

5.1.2.8 Weather Data. Hourly weather may be obtained from the National Climatic Center at the following address:

NATIONAL CLIMATIC CENTER OF
NATIONAL OCEANIC and ATMOSPHERIC
ADMINISTRATION
U.S. Department of Commerce
Environmental Data Center
Federal Building
Ashville, N.C. 28801

5.1.3 AXCESS ENERGY ANALYSIS COMPUTER PROGRAM. The AXCESS Energy Analysis Computer Program developed by the Electric Energy Association (EEA), is a means for estimating the difference in energy consumption and demand for up to six different mechanical/electrical designs for a planned building, or complex of buildings. Effectively a comprehensive feasibility study method, AXCESS is divided into 4 sections. The first three sections cover the engineering phases, each of which provides monthly and annual monetary values:

(1) ENERGY ANALYSIS - The cost of supplying all of the energy needs of a building in which alternate mechanical/electrical systems are to be considered.

(2) FIRST COST DIFFERENTIALS - The first cost differentials between such alternate systems.

(3) MAINTENANCE & OPERATING PERSONNEL COSTS - Differentials in cost for operating personnel, maintenance and unscheduled repairs.

(4) FINANCIAL ANALYSIS - The engineering-derived dollar values are utilized in methods of evaluation meaningful to the investor, i.e., rate of return on the investment, yield, discounted cash flow or net present value. These techniques are covered in a separate training manual developed by Price Waterhouse & Co. In addition, a computer program to perform the analyses is available from EEA.

5.1.3.1 Program Method. Using the input design loads, the program calculates hourly zone solar and transmission loads for the year. If desired, these may be input from another program. The program calculates the base energy loads each hour as the profile percentage multiplied by the peak usage, taking proper credit for any waste heat application. From these and zone data, it then calculates the zone internal gains and the net zone space conditioning requirement. Terminal system operation is simulated in one of ten subroutines using input set-points or "standard"designs. Based on the input performance data, and the calculated loads, each primary system is then simulated in one of three general subroutines. All calculated energy

usages are summed hourly into "meters". These meters function exactly as electrical usage and demand meters but may be used with any fuel. A unique feature of the program is its ability to receive as input a variety of thermal load types. The user may input hourly, zone-by-zone loads, as derived from other programs. If hourly and zonal loads are not available, the user may input building total loads with or without a breakdown between glass, wall and roof transmission values and solar loads, either as a design total or on an exposure-by-exposure basis. This is one of the program features which make it extremely practicable at various stages of building systems design. Most of the HVAC systems in popular use today are simulated in the computer. These systems range from unitary equipment to the most complex systems (at least from the standpoint of estimating energy consumption), such as heat recovery cycles and ceiling induction units utilizing lighting cavity heat. HVAC simulations are broken down by terminal and primary system types. Not only does this allow extreme flexibility in formulating an energy analysis study but it also provides ideal latitude in keeping the program always up-to-date. When any new terminal or primary system appears in the future, a new subroutine may be written and added in modular form to the existing computer program. On-site systems have been simulated on a modular basis so that any combination of HVAC terminals and primaries may be included with them in a particular scheme. Both thermal balance and electrical balance isolated generation systems may be studied. Up to six separate mechanical/electrical systems may be analyzed on a single computer run. In addition, a unique metering stage allows the user to benefit from supplementary information supplied from within each of the six schemes. The program uses standard engineering principles but bases all its calculations on input; so that as the quality of input increases, so will the quality of the output. It is well, however, to remember that the program's purpose is to provide a comparison of alternate designs, and the results for each scheme have more validity when viewed in relation to each other. The program's basic calculations and reset guidelines conform to standard engineering practice and are consistent with publications of ASHRAE.

5.1.3.2 Program Input. The program input is of two types - that provided by the user for a particular job, and that provided from other sources, usually standard, such as hourly weather data. The non-user input consists of the weather data and control information and is covered in the program description manual. The weather data is obtained from the National Climatic Center (see Section 5.1.2.8 for address) in a format for use with AXCESS. The user merely selects a weather station and year although it is possible to select a composite weather year if that is considered desirable. Weather data used in the program are hourly readings of dry-bulb temperature, percent relative humidity and cloud cover factor. The user input is divided into four groups - physical dimensions and description, HVAC information, other energy uses, and fuel/energy sources. These are further subdivided into nine sections on the field note input forms. The nine subsections of input are as follows:

(1) Section I is project description data. This includes general information for identification purposes as well as basic building operation and dimensions.

(2) Section II covers the base load items of usage. Each of the basic non-HVAC loads may be described via an installed KW or peak BTU and a "profile" describing the percent usage each hour. The input reference section of this manual contains typical profiles for some loads. The magnitude of the interior lighting load may vary among schemes and up to six different interior lighting loads may be described. Only one of each of the other pre-titled base loads is allowed, but up to thirty "other items of usage" may be input. There is also a total limit of thirty base load items of usage. Any base load may be referenced to any profile and there is a limit of thirty profiles. The profiles may be changed during a "special period" of building operation (such as summer session for a school). There is no limit on the number of special periods. Any of these loads may be partially or totally met by waste heat from an HVAC system or from another base load. (For example, domestic hot water preheated by rejected heat from a heat pump.)

(3) Section III is the input of design heating and

cooling load data sufficient for the program to calculate hourly skin loads. Most of the information in this section is optional. The "building construction" data is not used to calculate thermal loads but rather to calculate the time lag of these loads.

(4) Section IV is input for space type data. A space type is an optional collection of zones of similar usage. The space type input may be used in lieu of zone input for items common to each zone. Any differences may be input later in zone data, which overrides space data. For example, five office zones may differ only in exposure and in that one has an additional internal gain. Only that one zone would need a separate input form, while the rest of the information for all five zones could be incorporated into one space type.

(5) Section V is zone data. Every thermal energy-using area of the building must be either within a zone or broken up into zones. On page one of this section, the information correlating zones, exposures and space types must be entered, but the zone input forms may be omitted for any zone whose data may be approximated by the program from the space type or building input.

(6) The first HVAC systems data is entered in Section VI of the input. The first entries of that portion of the input which may vary in alternate schemes and must be repeated for each scheme is also made in this section. It serves to identify those terminal (distribution) system loads which are met by a given primary energy conversion system - such as the cooling coil load of a terminal system being served by a chiller. This input also serves to identify which terminal systems serve which zones, which other primary systems use energy from this one, or vice-versa, and whether waste heat is available from this primary system. Most of the information in this section is mandatory.

(7) Section VII includes a description of each terminal system. Almost all of this section is optional. If the type of system is the only input given, the program will assume certain standard design parameters such as a 55°F. cold deck set-point.

(8) Section VIII includes a description of each primary system with its full load performance, mode of operation, part-load efficiencies, and auxiliaries.

(9) Section IX serves to design the output format. Here all the energy-using devices under consideration are grouped into "meters" and "submeters", named, and assigned to energy sources.

5.1.3.3 Program Output. Basic program output consists of: (1) a complete printout of input data for verification purposes; and (2) monthly and annual statements of energy usage and demand by energy source type.

5.1.3.3.1 A sample calculation in which the calculation is printed out for a selected day, hour, zone and scheme. By comparing the procedure and results to this longhand calculation, the user may thus verify, by spot-checking, the accuracy of the program.

5.1.3.3.2 Breakdowns of energy usage by load types as dictated by the user's selection of simulated meters and submeters.

5.1.3.3.3 Monthly total heat rejected from air-cooled or water-cooled primary refrigeration systems.

5.1.3.3.4 Hourly and/or monthly deficit or excess kwh for thermal balance isolated generation systems.

5.1.3.3.5 Hourly or daily energy usage for each meter.

5.1.3.4 Program Availability. The AXCESS Energy Analysis program is available for use by NAVFAC Engineering field divisions through the computer located at the Facility Systems Office, Port Hueneme, California. The AXCESS Energy Analysis program was released to investor-owned electric utilities through a nationwide series of user training programs beginning in November 1972. Each of these companies has been furnished with a program source deck, user's manual and all other materials necessary for implementation on its own computer. AXCESS is also available to these utilities through a remote service bureau. Inquiries should be addressed to:

Electric Energy Association
Ninety Park Avenue
New York, New York 10016
Phone: (212) 986-4154

5.1.4 ECUBE - ENERGY CONSERVATION USING BETTER ENGINEERING. ECUBE (Energy Conservation Using Better Engineering) is an integrated series of energy analysis computer programs available from the American Gas Association. It evaluates energy systems to determine which equipment most economically satisfies the energy requirements of a particular structure. The program weighs the effects of weather, orientation, usage profiles, lights, motors and varying ventilation requirements on the system and generates reports which indicate the amounts of energy the site will consume with alternative types of equipment. It also provides data on economic comparison, based on factors such as equipment characteristics, local weather profiles, interest charges, and fuel and electrical costs. The ECUBE program series was initially developed to satisfy three requirements: (1) to integrate design point calculations of peak thermal and electrical load for making a realistic estimate of the hourly, monthly and annual energy requirements of a building; (2) to determine the energy consumption of various types of systems; and (3) to compare the total owning and operating costs of the various systems being considered. The programs analyze energy systems, including diesel, gas reciprocating engines, gas turbines, all-electric configurations and conventional configurations such as chillers and boilers. In addition, the programs weigh the effects of differing zones that require varying physical conditions and schedules. The program series consists of three basic computer programs, each designed to do a particular segment of an analysis, starting with design data and culminating in an economic comparison.

5.1.4.1 Energy Requirements Program. The ECUBE series starts with an analysis of the energy requirements for a building. This is accomplished by simulating the building with a computerized model and using historical hourly weather data furnished by the user. This program takes design point values for seven components of thermal load and the base component electric load, and distributes them over each hour of the year in accordance with dry bulb and dew point temperature variations, solar and cloud variations, and building use and operation schedules for various types of operational days. The program will evaluate the effects of thermostat setback or periodic system shutdown, as well as the resulting thermal storage and lag effects. This

feature permits the user to evaluate the change in energy requirements resulting from shutting the system off at night or on weekends, or of resetting the thermostat during periods of non-occupancy. The program also shows how often heating and cooling system limits are reached when operating with either of these features. Simultaneous heating and cooling characteristics of dual-duct or terminal reheat systems can be accommodated. The out-put of this portion consists of a tape with hourly values of thermal and electrical load; a print-out of peak heating, cooling, electrical and process loads each month; the time that they occurred; and the cumulative values of each load type. The complete Energy Requirements run is stored on magnetic tape for future use with the Equipment Selection and Energy Consumption Program.

5.1.4.2 Equipment Selection and Energy Consumption. This second program in the series is designed to simulate the operation of equipment as required to meet the hourly loads stored on magnetic tape developed by the Energy Requirements program. Up to four types of systems can be evaluated with each run. The operating characteristics of any type of generator set, chilller, boiler, or heater are input to the program. The printout is a monthly summary of the gas, auxilliary fuel and electricity consumed; the peak electric demand; the number of operating hours of each generator and chiller; and an evaluation of thermal energy usage.

5.1.4.3 Economic Comparison Program. The Economic Comparison program helps the designer make the rational choices among various alternative solutions to the problem. Three categories of information are required; (1) project capital requirements; (2) project annual operating costs; and (3) details concerning the methods of financing and criteria for judging economic feasibility. Development of annual operating costs (maintenance, fuels, etc.), capital costs and financial criteria is the responsibility of the program user. The feasibility of alternative system designs is compared to a base or reference system. Many options are included in the programming to evaluate the financial particulars of each client so that the detailed methods of financing are properly weighed in the rate of return analysis. The Economic Comparison Program is not

directly tied to the first and second parts, so it can also be used on other types of engineering projects which require concise financial evaluation.

5.1.4.4 Supplementary Programs. Three supplementary programs are also available for modeling solar conditions and weather conditions, and for the summation of loads when several building or parts of buildings are analyzed separately. The three programs are as follows:

5.1.4.4.1 Solar Distribution. This program accurately simulates the solar conditions that affect the structure being evaluated by utilizing the maximum solar value for the building and, through an allocation procedure, correctly distributes the solar loading by hour and direction.

5.1.4.4.2 Weather Check. The Weather Check program takes the weather data that the user develops or gets from the U. S. Weather Services and converts it in a format usable by the main portion of the program.

5.1.4.4.3 Summation of Energy Requirements. This program is used when loads from zones of one building or several buildings are to be input as one system into the Equipment Selection and Energy Consumption program. Sums of the heating, cooling, electrical and process heat loads are produced for all the buildings generated by the Energy Requirements program for each hour of the year.

5.1.4.5 Availability. Further information concerning the use and availability of the ECUBE program may be obtained from the American Gas Association. Inquiries should be directed as follows:

Mr. Kenneth Cuccinelli
Manager, Energy Systems and
Energy Systems Analysis
AMERICAN GAS ASSOCIATION
1515 Wilson Boulevard
Arlington, Virginia 22209

5.1.5 MACE - McDONNELL ANNUAL CONSUMPTION OF ENERGY. McDonnell Douglas Automation Company's Annual Consumption of Energy Program (MACE) is designed to estimate the total annual energy requirements of a building by making hour by hour loads analysis and system simulations. Since the majority of commercial buildings have internal activities and operations that are cyclic by week, time schedules controlling these activities and operations are designed to handle a weekly schedule. The user can specify the "hour on" and "hour off" for weekdays, Saturdays, and Sundays. The program allows the user to select any given month or months to be analyzed if he is interested only in the totals for a few selected months. The user can also select the analysis to be made for one, two, or four weeks (all days per month). If one week per month is selected, the analysis is made for the first week of the month and the same energy requirements are assumed for the remaining three weeks. If two weeks per month are selected, the first and third weeks are analyzed and the same energy requirements are assumed for the second and fourth weeks respectively. This feature allows the user to reduce calculation time with a possible loss in accuracy; but, still get meaningful monthly and yearly totals. There are basically three main sections to the program each of which overlays the other.

(1) Input Section. This set of subprograms reads in the input model, does extensive error checking and converts the input model into an internal format designed for optimal execution of the loads and systems analysis. The internal input model can be checkpointed for future processing of the job.

(2) Loads Analysis and System Simulation Sections. This set of subprograms calculates the hour by hour loads and system simulation. The monthly energy usage and demand usage is saved for the economics analysis. The hourly space loads can be saved for future system analysis studies.

(3) Economics Section. This set of subprograms calculates the cost of energy using the energy rate schedules input by the user. Monthly and yearly energy usage totals and costs are printed.

The hourly load and system simulation procedures require hourly values of dry bulb temperature, wet bulb temperature, total cloud amount, cloud type, wind velocity, wind direction and barometric pressure. The basic source of weather data is from the National Climatic Center (see Section 5.1.2.8 for address). Weather data is available for major cities and many other localities for many past years. McDonnell Douglas Automation Company is building a library of weather data on a user requirement basis and currently has available ten year data for several cities. The selection of a particular year of data to be used for an energy analysis can be handled by consultations of the user with McDonnell Douglas Automation Company Engineers.

5.1.5.1 Program Input. Careful attention has been given to the input requirements of the MACE program. Insofar as possible, only data that is readily available to the user is required for the program. Most of the data may be taken directly from the building plans. The following data are required for input to the program:

(1) Identification of the job and other user comments.

(2) Specification of the weather data to be used.

(3) Designation of the months for which calculations are to be made and if one, two, or all weeks of these months will be computed.

(4) Specification of wall and roof type.

(5) Window description, including dimensions and type of glass; exterior shading features including setback, overhang and fins; and leakage factor of windows.

(6) Floor, partition and door dimensions, and "U" values.

(7) Specification of wall, roof, and window types, and number of windows that are to be assigned to each space.

(8) Master time schedules and loads that conform to these time schedules, such as: occupants, lights, appliances and miscellaneous energy usage.

(9) Designation of duplicate space numbers for spaces that are identical to those already described.

(10) Specification of system types and methods of control.

(11) Performance characteristics of components.

(12) Energy rate structures, including data on graduated rates and demand charges.

(13) Designation of printouts that are desired in addition to the monthly and annual energy consumption and costs.

5.1.5.2 Output. The type and frequency of output is controlled by the user at input time by the time scheduled print options. The following general categories of output are available to the user:

(1) Printout of the input model by day type categories which helps in checking the input for completeness and validity.

(2) Printout of hourly space and building loads for specified days.

(3) Printout of the hourly system simulation operating variable for specified days.

(4) Printout of the electrical usage and cost (including lights, miscellaneous, heating and cooling system and auxiliaries) on an hourly basis for specified days and monthly and yearly totals.

(5) Printout of fuel consumption and cost on an hourly basis for specified days and monthly and yearly totals.

5.1.5.3 Availability. Additional information can be obtained from:

McDonnell-Douglas Automation Company
Marketing Services
Box 516
St. Louis, Missouri

5.1.6 TRANE AIR CONDITIONING ECONOMICS (TRACE). Trane Air Conditioning Economics (TRACE) compares the economic impact of such building alternatives as architectural features, HVAC systems, HVAC equipment, scheduling and economic alternatives.* Trane Air Conditioning Economics evaluates up to four alternatives and compares the six possible combinations. Trane Air Conditioning Economics, simulates system operation for each zone of a building, each hour of the day to arrive at annual operating costs. A U. S. Weather Bureau tape provides data from the most recent in ten years and the computer reduces it to twelve days (one typical day for each month), representing a typical year. This creates a typical external load for a building. The weather tape also provides hourly information for an entire year on such items as dry bulb, wet bulb, dew point temperatures, wind velocity and cloud cover modifiers. This data is compiled and averaged for each month of the year to arrive at a typical 24 hour period for that month. Deviations are recorded from an average temperature for each hour. Weather tapes for 150 cities are available that give the hourly climatic conditions to be expected. TRACE consists of five major phases: load, design, system, equipment and economics, explained as follows:

5.1.6.1. Load Phase. In the load phase conventional load input data describing the building and its thermal-time characteristics are entered. Weather data from a U. S. Weather Bureau tape is fed in next to simulate actual weather conditions. Loads are calculated by zone by hour for a full year. To calculate solar loads, the program allows for such factors as location, orientation and altitude of the building. Transmission loads are found from heat transfer coefficients, square footage for load allocations and summer and winter design temperatures. Internal loads are calculated using input on lights, people and equipment. Ten standard schedules and ten optional schedules are available to describe the use of the building.

---

*NAVFAC experience indicates that the economic analysis performed by this program does not conform to NAVFAC P-442.

This will provide the load diversity due to such items as occupancy, lights and equipment for any hour of the day. There is also a base utility schedule to account for energy used outside the conditioned spaces. The computer tracks this consumption by hour and adds to the cooling or heating energy consumptions for that hour so that accurate energy rates will be used. A typical example of base utility is outside lighting.

5.1.6.2 Design Phase. In the design phase, the type mechanical system to be used is described. The design phase receives input from the load phase and such items from the user as zone to system load assignment and amount of minimum outside air required. It also picks up block loads, peak loads by zone, and room design from the load phase. After calculating the system sensible heat ratios, the program uses a psychrometric repeat loop to calculate supply air dry bulb temperatures to each zone. It can then calculate the supply air quantities required to handle the load in each zone. The system supply air quantity is then found by adding the zone cfm's or using block loads.

5.1.6.3 System Simulation Phase. System simulation phase picks up the sensible and latent load by zone from the load phase and calculates return air quantities and temperatures. If applicable, this phase picks up any return air loads such as lights and roof. It also calculates the mixture temperature when mixed with outside air. Temperatures of outside air are derived from the weather tapes. The final step of system simulation is to calculate loads peculiar to the mechanical system itself. Most all types of air conditioning systems can be used for either the perimeter or interior. Included are high velocity variable air, low velocity variable air, double duct, multizone, terminal reheat, packaged terminal air conditioner, hydronic heat pump, fan-coil, induction, radiation and variable temperature constant volume. And nearly 60 types of cooling, heating, and air handling equipment can be used. The full and part load data mainly for TRANE equipment is stored on the equipment performance tape. Performance characteristics of other manufacturers' equipment can be substituted.

5.1.6.4 Equipment Simulation Phase. The equipment simulation phase uses output from the system simulation phase plus user input on the type of cooling and heating equipment, fans and pumps to determine the cooling load on the refrigeration equipment, heating load on the heating equipment, humidification load and supply and return fan air quantities. This allows full and part load efficiencies to be assigned to each piece of equipment that uses energy. Outdoor weather data modifies part load efficiencies. Using the equipment load by system from the system simulation phases, the equipment simulation phase generates monthly energy consumption by utility type.

5.1.6.5 Economic Analysis Phase. The economic analysis phase uses utility consumption from the equipment phase and user input such as utility rate structure. At this stage, the user also inputs installed cost and maintenance costs for the project. These costs must be analyzed carefully to give objective results. The economic phase then generates the economic comparisons of alternatives chosen. The output from TRACE compares the effects of the alternatives being considered. It is expressed in terms owners ordinarily use, such as present worth, pay back and return on investment. In addition, annualized owning and operating costs are part of each alternative output. This is beneficial to the institutional and government building owner.

5.1.6.7 Availability. TRACE is available through professional engineers. The local Trane commercial air conditioning office in each city is equipped to give more information.

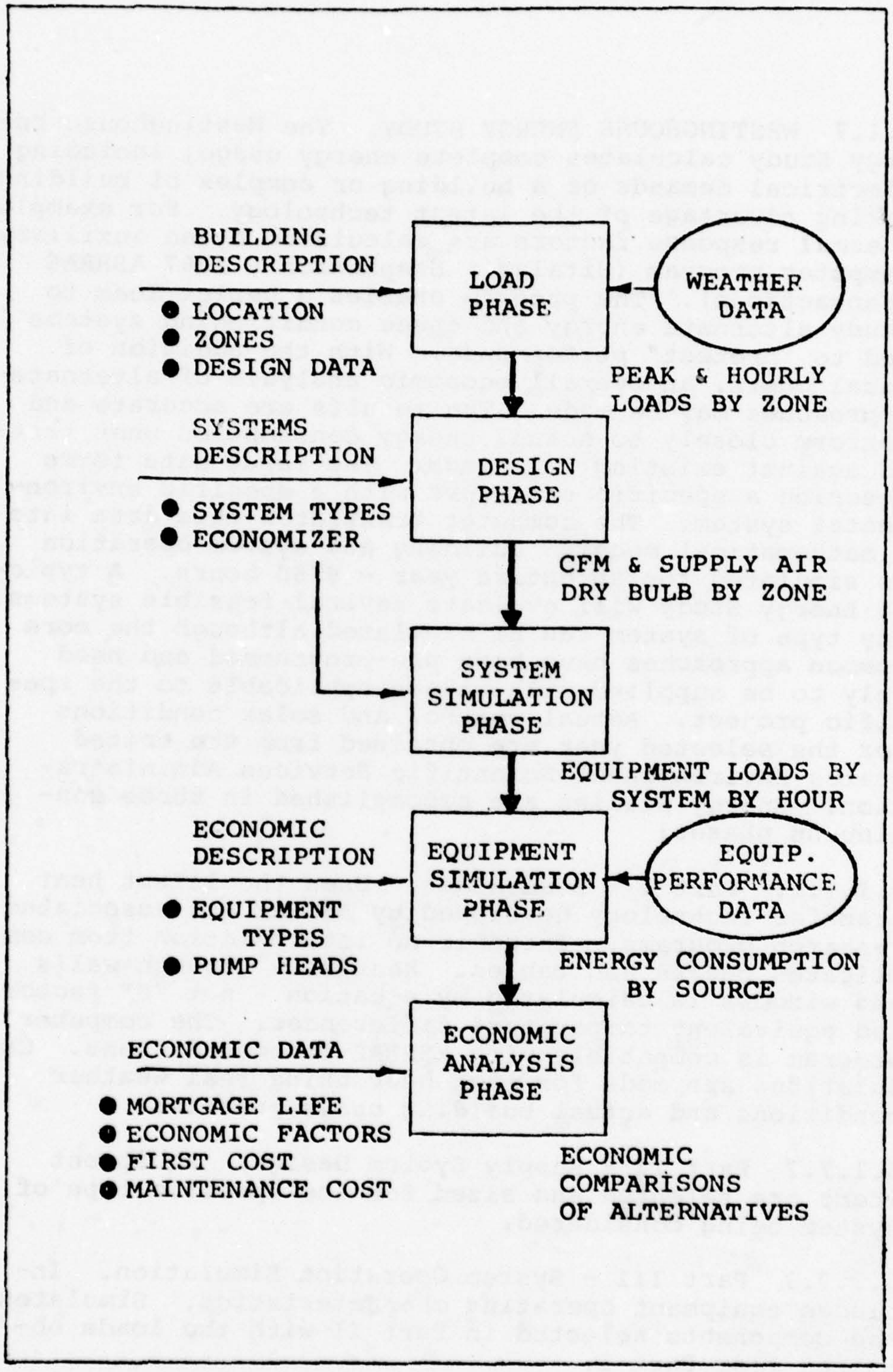


FIGURE 5-2

TRACE - CALCULATION FLOW CHART

5.1.7 WESTINGHOUSE ENERGY STUDY. The Westinghouse Energy Study calculates complete energy usage, including electrical demands of a building or complex of buildings, taking advantage of the latest technology. For example, thermal response factors are calculated by an auxiliary computer program (Mitalas & Stephenson - 1967 ASHRAE Transactions). The program enables a Design Team to study alternate energy and space conditioning systems and to "pretest" performance. With the addition of local costs, an overall economic analysis of alternate approaches may be made. The results are accurate and conform closely to actual energy consumption when tested against existing buildings. The input data forms describe a specific structure with a specific environmental system. The computer translates this data into a mathematical model. Building and system operation is simulated for an entire year - 8760 hours. A typical Energy Study will evaluate several feasible systems. Any type of system can be simulated although the more common approaches have been pre-programmed and need only to be supplied with values applicable to the specific project. Actual weather and solar conditions for the selected year are obtained from the United States Environmental Scientific Services Administration. Energy Studies are accomplished in three continuous phases:

5.1.7.1. Part I - Load Model. Uses the latest heat transfer technology developed by ASHRAE and associated research programs. There is no interpolation from complicated charts and tables. Heat flow through walls and windows is calculated by equation - not "U" factors and equivalent temperature differences. The computer program is compatible with ASHRAE recommendations. Calculations are made for each hour using real weather conditions and actual building usage profiles.

5.1.7.2 Part II - Supply System Design. Equipment items are selected and sized for the specific type of system being considered.

5.1.7.3 Part III - System Operation Simulation. Includes equipment operating characteristics. Simulates the components selected in Part II with the loads obtained from Part I.

5.1.7.4 Availability. Additional information and pricing details may be obtained from Westinghouse Major Projects and Urban Systems representatives who are located in major cities. Inquiries may be addressed to:

Westinghouse Electric Corporation
The Energy Utilization Project
Power Systems Planning
700 Braddock Avenue
East Pittsburgh, Penna. 15112

5.1.8 HEATING-COOLING CALCULATION (HCC-III). HCC-III is an advanced computerized procedure for calculating design heating and cooling loads for buildings in accordance with ASHPAE methodology. The program is unique in that it is based on a "down to earth" approach, having been developed by a group of outstanding design professionals for their own use. It thus not only incorporates those design aspects of most critical interest to the designer, but analyzes them with a thoroughness and degree of sophistication impossible before computerization. By combining ASHRAE techniques with engineering experience, the program avoids compromises with internationally recognized porcedures. As a design program, HCC-III is oriented to the design professional as a tool to develop the necessary information in a recognized manner and in such a way as to facilitate use of the output directly, without manual manipulation. Apart from design benefits, which are numerous, production costs per job have been reduced by application of the most advanced programming techniques.

5.1.8.1. Administrative Benefits.

(1) Standardization of calculation procedures (avoiding parochiolism, or idiosyncrasies of individual designers).

(2) Improvement of record keeping and calculation format.

(3) Utilization of lower echelon personnel for physical data takeoff, freeing design engineers for more significant decisions.

(4) Cost reduction of calculation procedures, with no sacrifice in thoroughness or quality.

5.1.8.2 Technical Benefits.

(1) Provide cooling load calculations on a 24 hour basis, comparing hourly totals for determination of true peak hour for each room, air handling system (zone), and for the entire building.

(2) Take into account thermal storage effect of building mass and contents on radiant components of both

transmission loads from the exterior and internal loads from lighting, people, and appliances.

(3) Consider all types of environmental surfaces affecting cooling and heating loads, and provide means to minimize input effort in directing their evaluation for individual spaces.

(4) Provide a means to analyze the effects of using a ceiling return air plenum system, including the reduced effect on room sensible loads and the increased effect on the air handling unit coil resulting from increased return air temperature.

(5) Calculate the shading effectiveness of any combination of window overhang and/or side fins in evaluating the solar components of glass loads.

(6) Consider the effect of varying glass types and glazing arrangements as well as interior shading devices, and the angle of exposure of glass to the sun, whether vertical, sloped, or a skylight.

(7) Take into account the varying effects on system loads and room CFM values of system type, whether variable volume, terminal reheat, or conventional mixed air.

(8) Calculate room CFM values (including Project altitude consideration) on either an input dehumidified temperature rise or a calculated apparatus dew point method, and sum them into designated air systems.

(9) Calculate ventilation air CFM values based on a variety of optional factors.

(10) Analyze thermodynamically the resultant air mixture entering and leaving the cooling coil, including the effects of supply fan location, use of return and/or outside air fans, coil bypass factor, estimated static pressures, and supply duct heat gain, for the purpose of determining maintained space humidity ratios and actual maximum cooling coil loads.

(11) Minimize input requirements by utilizing to the fullest possible extent the concept of "master"

data, with individual "over-ride" capabilities at more specific levels.

(12) Solar calculations take geographic factors into account including longitude and latitude, altitude, building orientation, atmospheric clearness and ground reflectivity.

(13) Minimize re-run effort in event of project modification by retaining in systems data file storage all input and result data; permitting re-input of only the modified areas, and recalculation and result analysis of only the parts and systems thus affected.

(14) Maximize program practicality by providing optional interface with available equipment selection programs for simultaneous output.

5.1.8.3 Availability. HCC-III was developed by Automated Procedures for Engineering Consultants, Inc. (APEC). Access to the APEC program is restricted to APEC member firms. Information on membership, a descriptive abstract of the program, and access procedures may be obtained from:

Doris J. Wallace
APEC, INC.
Suite M-15, Grant-Deneau Tower
Dayton, Ohio 45402

Section 2. MINIMUM REQUIRED DESIGN PARAMETERS

5.2.1 INPUT. In this section, the types of information which can be input to computer programs for an energy system analysis are listed. The information is typical of that required for all computer programs and is dependent on the program used, the point in the design process at which the analysis is made, and the degree of accuracy desired in the results. Only information necessary for an energy analysis is shown. Information for the calculations of heating and cooling load is not shown although it is required in some cases.

5.2.2 BUILDING INFORMATION.

5.2.2.1 General.

(1) Area to be Air Conditioned

(2) Solar Area Percentages for Each Direction.

(3) Heat Storage Effect of Building and Hours for Spread.

5.2.2.2 Design Conditions for Heating and Cooling.

(1) Ambient Dry Bulb and Dew Point.

(2) Indoor Thermostat Settings for Dry Bulb and Dew Point.

5.2.2.3 Heating and Cooling Maximum Loads.

(1) Solar

(2) People

(3) Lights

(4) Equipment

(5) Miscellaneous

(6) Design Transmission Loads

5.2.2.4 Other Type Maximum Loads.

(1) Base Electric

(2) Process Heat with Type Firing

5.2.2.5 Operational Day Types and Schedules.

(1) Shut-off and Set Back Time Schedule for Heating, Cooling, Outside Air, Set Back

(2) Percent Variation Profile Followed by Each Load Type

(3) Months Each Day Type Occurs

(4) Days of Week Each Day Type Occurs

(5) Holidays

5.2.3 SYSTEM INFORMATION

5.2.3.1 Type.

5.2.3.2 Capacities for Heating and Cooling Systems.

5.2.3.3 Operation Schedules and Keys.

(1) Part Load Percent Variation Profiles - Used for describing part load performance for chillers, boilers, and generators by representing primary and auxillary fuel input curves, available recoverable heat curves, and accessory equipment input curves.

(2) Ambient Temperature Effect Profiles - Used for describing the ambient temperature effects on the rated capacities of chillers, generators, and cooling towers. Temperatures may be either ambient dry bulb, ambient wet bulb, or condenser water temperatures.

(3) Limitation Schedules

(4) Equipment Groupings and Operation Keys for Each System

Section 2. MINIMUM REQUIRED DESIGN PARAMETERS

5.2.1 INPUT. In this section, the types of information which can be input to computer programs for an energy system analysis are listed. The information is typical of that required for all computer programs and is dependent on the program used, the point in the design process at which the analysis is made, and the degree of accuracy desired in the results. Only information necessary for an energy analysis is shown. Information for the calculations of heating and cooling load is not shown although it is required in some cases.

5.2.2 BUILDING INFORMATION.

5.2.2.1 General.

(1) Area to be Air Conditioned

(2) Solar Area Percentages for Each Direction.

(3) Heat Storage Effect of Building and Hours for Spread.

5.2.2.2 Design Conditions for Heating and Cooling.

(1) Ambient Dry Bulb and Dew Point.

(2) Indoor Thermostat Settings for Dry Bulb and Dew Point.

5.2.2.3 Heating and Cooling Maximum Loads.

(1) Solar

(2) People

(3) Lights

(4) Equipment

(5) Miscellaneous

(6) Design Transmission Loads

5.2.3.4 Controls.

(1) Upper and Lower Limits for Economizer

(2) Humidification Reset

(3) Hot Deck Temperature Schedules

(4) Fan Operation Method

5.2.3.5 Air Flow.

(1) Total Supply Air

(2) Maximum Cold Deck and Hot Deck Air

(3) Maximum Outside Air

(4) Minimum Outside Air During Heating, Cooling, and Unoccupied Periods

(5) Minimum Percent for Variable Volume Systems

(6) Air Temperature Rise for Fans

(7) Primary and Secondary Supply Air Temperatures and Humidity Ratios

5.2.4 EQUIPMENT.

5.2.4.1 Chiller Characteristics.

(1) Type (direct/indirect fired absorption, steam turbine driven, etc.)

(2) Minimum Load for Starting Unit (base on manufacturers recommendation)

(3) Rated Output

(4) Maximum Primary Energy (Electricity, Gas, Oil, etc.) Input at Rated Output

(5) Maximum Recoverable Heat at Rated Output

(6) Maximum Auxiliary Energy (Electricity, Gas, Oil, etc.) Input at Rated Output

(7) Pilot Fuel Input for Dual Engines

(8) Accessory Loads with Type Accessory

(9) Part-Load Percent Profiles for Operation (See 5.2.3.3)

(10) Ambient Temperature Profiles for Operation (See 5.2.3.3)

5.2.4.2 Generator Characteristics.

(1) Type Drive

(2) Rated Output

(3) Maximum Primary Energy (Elec., Oil, Gas, etc.) input at rated output

(4) Maximum Recoverable Heat at Rated Output

(5) Maximum Auxiliary Energy (Elec., Oil, Gas, etc.) Input at Rated Output

(6) Pilot Fuel Input for Dual Engines

(7) Accessory Loads with Type Accessory

(8) Part Load Percent Profile for Operation (See 5.2.3.3)

(9) Ambient Temperature Profiles for Operation (See 5.2.3.3)

5.2.4.3 Boiler, Process Heat Equipment, Heat Pumps Characteristics.

(1) Type

(2) Rated Output

(3) Energy Input at Rated Output

(4) Accessory Loads with Type Accessory

(5) Part-Load Percent Profiles for Operation (See 5.2.3.3)

(6) Ambient Temperature Profiles for Operation (See 5.2.3.3)

5.2.4.4 Cooling Tower.

(1) Fan Kilowatt

(2) Ambient Temperature Profiles

5.2.5 ENERGY FORM

5.2.5.1 Auxiliary Forms

(1) Amount per Unit

(2) Cost per Unit

(3) Heating Value of Fuel

5.2.5.2 Other Forms (Gas, Electricity, Steam, Chilled Water, Hot Water).

(1) Heating Value of Gas

(2) Charge - Monthly Minimum Fixed, Adjustment Rates

(3) Methods for Determining Charges

(4) Demand Rate Steps - Size, Method of Application, Cost

(5) Consumption Rate Steps - Size, Method of Application, Cost

(6) Energy Use Scheduling for Each System

5.2.6 ECONOMICS FOR EACH SYSTEM.

(1) Type Analysis (Follow NAVFAC P-442, Present Worth Method)

(2) Number of Years for Analysis

(3) Annual Costs for Energy Type

(4) Annual Costs for Maintenance, Operation, and Any Miscellaneous Costs

(5) Escalation Rates for Costs

(6) Initial Gross Investment with Percent Salvage

(7) Depreciation Methods

(8) Debt Amount with Interest Rate

(9) Equity Interest Rates

(10) Data for Reinvestments

Section 3. EXAMPLE - COMPUTER ANALYSIS OF AN EXISTING BUILDING

5.3.1 EXAMPLE BUILDING FOR COMPUTER SIMULATION. The selected example building for computer analysis of energy conservation and cost evaluation is a two-story, rectangular building. A complete building description, and input data is enclosed. The analysis is performed using Kling-Lindquist, Inc. Heating and Cooling Load (HECOL) program in conjunction with the Ross F. Meriwether Energy System Analysis (ESA) program. A description of HECOL is enclosed in this section. The analysis enables us to evaluate the effectiveness of each varying design parameter for energy conservation. The various parameters considered include insulation, glazing and use of heat recovery wheels. Base system selected is a constant volume, reheat system with perimeter radiation and enthalpy control.

5.3.1.1 Run 1. Run 1 is made using single glass, no wall or roof insulation and with building oriented with the longest exposure to north and south. The percentage of glass area is obtained from the drawing, a copy of which is enclosed.

5.3.1.2 Run 2. Run 2 is the same as Run 1, but with double glass.

5.3.1.3 Run 3. Run 3 is with wall and roof insulation to give $U_W = 0.08$ and $U_R = .05$.

5.3.1.4 Run 4. Run 4 uses heat recovery wheels and has no enthalpy cycle. The enthalpy cycle is not used in Run 4 to avoid hunting problems that are associated in system trying to use both.

5.3.1.5 Table Summary. A summary of all runs on pages 5-46 and 5-47 shows heating loads, cooling loads, energy usage, energy cost and present worth of owning and operating cost. Page 5-45 shows the estimated investment cost based on various assumptions as stated on the page. A copy of the building drawing and important

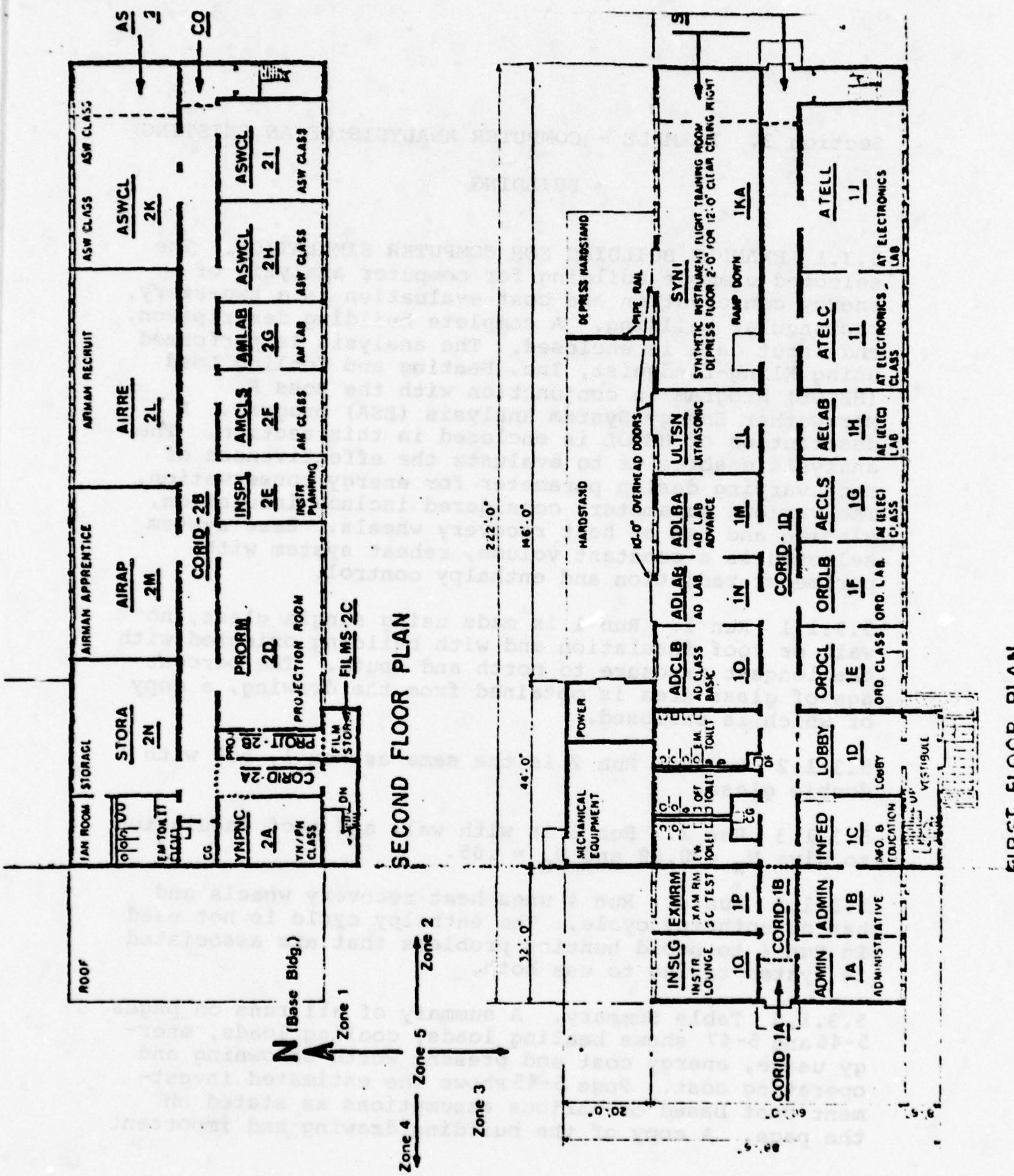


Figure 5-3

Example Building

Dimensions Obtained From Y & D Dwg No 873591 (171-10-B)

DATE 10/24/74 BY J.P.C.

SCALE 1" = 32'

JOB NO. 1335-00

HECOL as well as ESA printouts are enclosed. Complete detail of all printout data as well as all ESA input data is given in a separate binder.

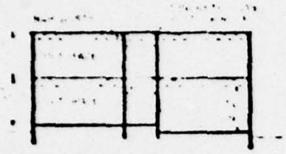
5.3.2 HECOL PROGRAM DESCRIPTION. Program "HECOL", code name for "Heating and Cooling Loads in Buildings," performs calculations of heating load in winter time and cooling load in summer time in buildings with specified design conditions. The calculation logics and procedures in HECOL follow closely the conventional practices in heating and cooling designs for buildings. The input data for the calculations can be divided into two groups:

5.3.2.1 Design Constants. Criteria chosen by the user for the building concerned, such as materials of construction, temperature ranges, etc.

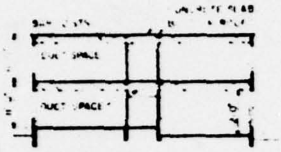
5.3.2.2 Design Dimensions. Physical requirements of the building, such as room sizes, glass areas, number of people and equipment housed, etc.

5.3.2.3 Groups. They are so organized that minimum repetition and maximum utilization of the input data are achieved for the program. Alternate designs for the same building can be obtained with very little effort by merely changing a few of the design constants and submitting to the program for a rerun. By similar reasoning, refinement designs for the same building can also be easily achieved by revising and updating the design dimensions of the building as the building is progressing from its preliminary to its final design stages.

5.3.3 DESCRIPTION OF THE INPUT DATA FOR ENERGY ANALYSIS. The selected example building for energy analysis is the "Aviation Technical Training Building" with physical dimensions obtained from Y & D Drawing No. 873591 (171-10-B). The building is two stories with a gross area of approximately 26,230 square feet, of which 23,136 square feet is the net air conditioned area. The ambient design parameters corresponding to the following frequency are for the Philadelphia area, from NAVFAC P-89, "Engineering Weather Data" issued 15 June 1967, page 54.



SECTION



SECTION

STEEL FRAME CONSTRUCTION

GRAPHIC SCALE

PLUMBING REQUIREMENTS

HOT WATER

RECOVERY RATE	
STORAGE	

MECHANICAL REQUIREMENTS (M BTU/HR)

HEATING

INSIDE DESIGN TEMPERATURE				70° F
OUTSIDE DESIGN TEMPERATURES	-5°F	+5°F	+15°F	+25°F
CURTAIN WALL FENESTRATED BLDG.	1650	1430	1210	990
MASONRY WALL NON-FENESTRATED BLDG.	1310	[illegible]	1110	910

AIR CONDITIONING

INSIDE DESIGN		80° FDB	50% RH
OUTSIDE DESIGN		95° FDB	78° FWB
COOLING LOAD			
CURTAIN WALL FENESTRATED BLDG.	[illegible]		
MASONRY WALL NON-FENESTRATED BLDG.	1080		

ELECTRICAL REQUIREMENTS (KW)

		WITH AIR-CONDITIONING
LIGHTS:		
CONNECTED	100	100
ESTIMATED DEMAND	75	75
POWER:		
CONNECTED	[illegible]	250
ESTIMATED DEMAND	[illegible]	225
TOTAL:		
CONNECTED	145	[illegible]
ESTIMATED DEMAND	110	[illegible]

AREA SQ. FT.

GROSS AREA WITH MECHANICAL EQUIP. ROOM	26,250 SQ. FT.
MECH. EQUIP. ROOM W/O AIR COND. (AVERAGE CONDITIONS)	[illegible] SQ. FT.
GROSS AREA (MAXIMUM ALLOWED)	26,250 SQ. FT.

GENERAL NOTES

THE ARRANGEMENT AND FUNCTIONAL LAYOUT INDICATED SHALL BE FOLLOWED UNLESS [illegible] CLEARANCE FOR CHANGE IS OBTAINED FROM THE [illegible]. THE ARCHITECTURAL TREATMENT, MATERIALS, FRAMING AND CONSTRUCTION MAY VARY.

UTILITIES REQUIREMENTS INDICATED ARE FOR ESTIMATING PURPOSES ONLY.

REVISED JULY 196[illegible]

GOENNER AND YOUNG

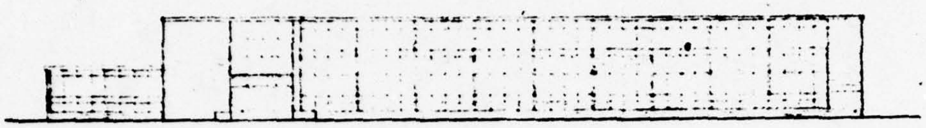
DEFINITIVE DRAWING

AVIATION TECHNICAL TRAINING

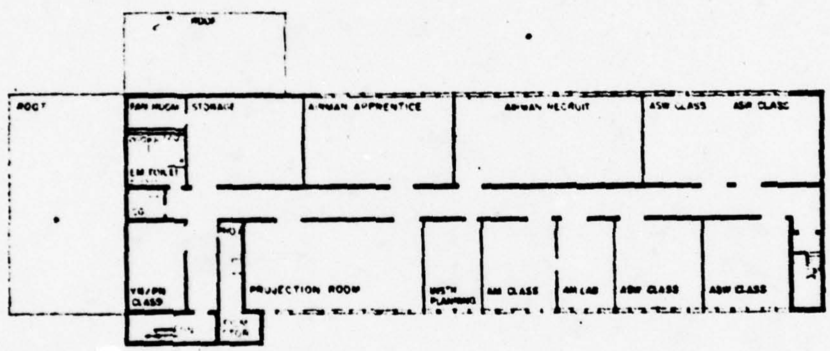
[redacted]

873591

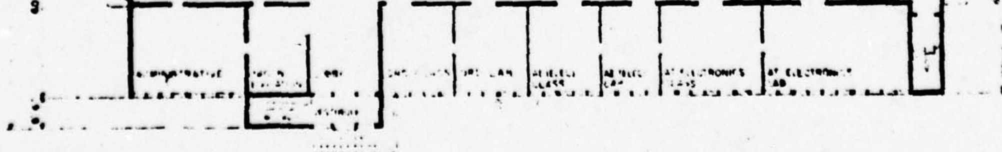
FRONT ELEVATION



FRONT ELEVATION



SECOND FLOOR PLAN



FIRST FLOOR PLAN

Season	Frequency	Ambient Temperatures
Summer Cooling	2-1/2% DB, 5% WB	91°F.DB, 76°F.WB
Winter Heating	97-1/2%	16°F.

5.3.3.1 Indoor Design Conditions. The indoor summer design is 76°F. DB and 50% RH (maximum). The indoor winter design is 70°F. and 25% RH. The peak internal load from 464 people (50 square feet/person) at 450 Btu/hour each is 208.8 KBH, of which 92.8 KBH, or approximately 44% is latent heat. The peak internal load (base electric) from lighting fixtures is 75 KW, which corresponds to 255 KBH. The peak internal load (base electric) from equipment within the conditioned space is 75 KW, including 1/2 watt per square foot for small power. The peak hot water requirements are based on the flow rate of 36 GPH, recovery rate through 100° rise (40-140). This gives a hot water load of 30 KBH

$$\frac{(36 \text{ GPH} \times 8.33 \text{ lb./gal.} \times 100° \text{ rise})}{1000 \text{ BTU/KBH}} = 30 \text{ KBH}$$

The building is assumed to have 8:00 A.M. to 4:30 P.M. work day operation from Monday through Friday with the air conditioning system on from 7:00 A.M. to 5:00 P.M. (occupied). The system is started at 7:00 A.M. to allow for pickup, and no outside air is provided from 7:00 A.M. to 8:00 A.M. The air system is completely shut off during the remaining hours and on Saturday, Sunday and holidays (unoccupied). The percentage variation in the load profile of occupancy, lighting, equipment, and hot water is considered on an hourly basis for both the occupied and the unoccupied periods. Partial lighting is left on from 5:00 P.M. to 7:00 P.M. for cleaning purposes. The basic heating system is perimeter radiation controlled by outdoor air stat, see Figure 5-4, and sized to offset transmission loss. Radiation heat output is reduced to zero at 55°F. night setback temperature. The heat load is furnished by one (1) hot water boiler, oil fired using #2 oil at 36¢ per gallon, with a temperature range from 160°F. to 180°F. Where reheat coils are used, the

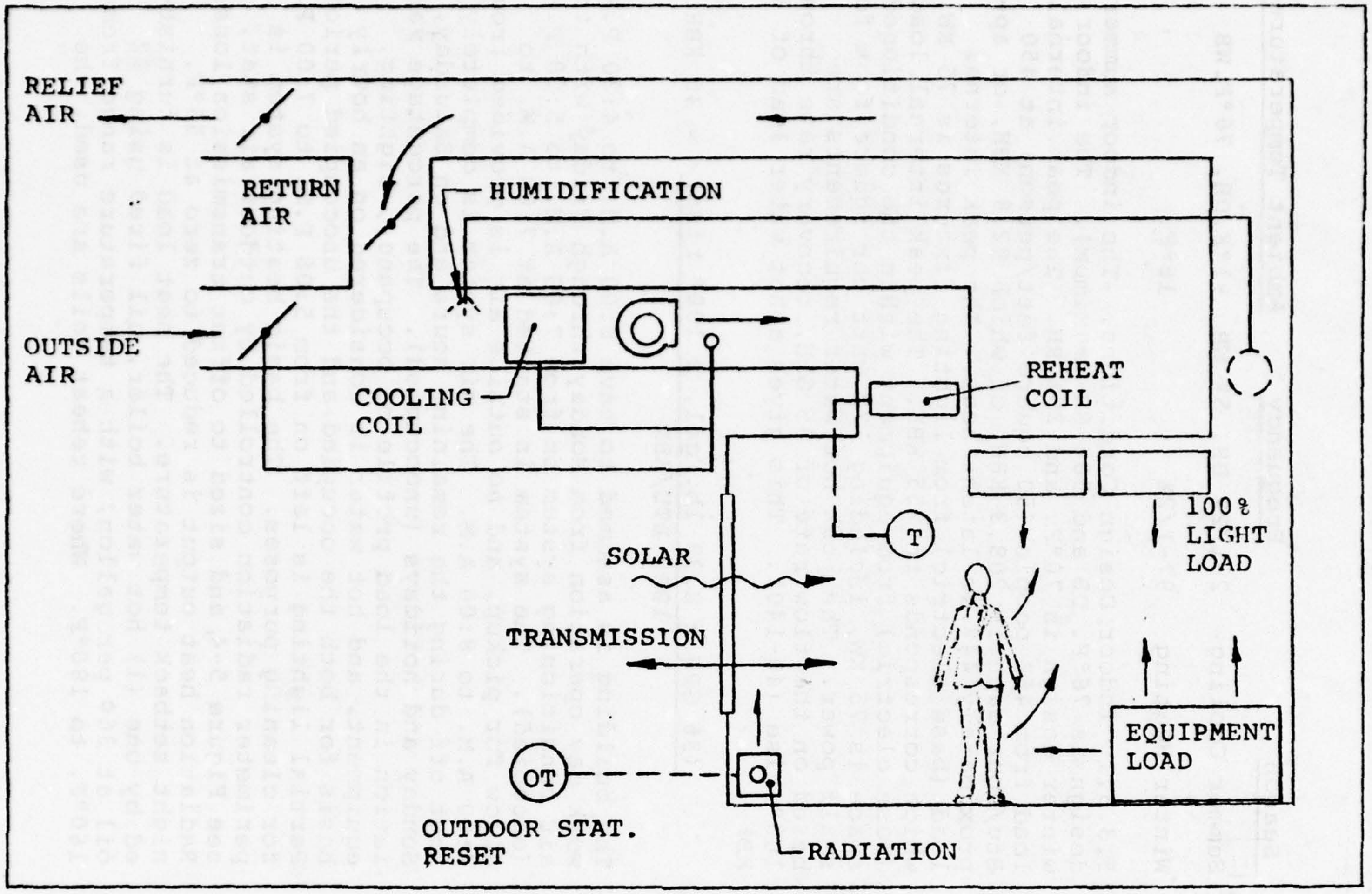


FIGURE 5-4

CONSTANT VOLUME WITH REHEAT AND PERIMETER RADIATION

boiler is sized to meet transmission loss, infiltration, reheat loads, and domestic hot water load. The cooling system is an electric driven centrifugal machine with water cooled condenser and energy input at peak equal to 1.0 KW/ton. The chiller flow is based on 42° to 62° range and condenser flow is based on 85° to 95° range. The air distribution is by two air handling systems (draw-thru), one for each floor. A 3° temperature rise is allowed due to fan gain. Ventilation of 5 CFM/person and infiltration of 1/2 air change per hour is used for load calculations. Enthalpy cycle where used utilizes outdoor air for cooling when ambient temperature is less than 60°F. and the outdoor enthalpy is lower than the room design enthalpy. The ceiling height of 8'-6" is assumed. Safety factors are not used in load calculations. Economic comparison of systems is based on the following figures obtained from NAVFAC INST 11010.55A: Life of 25 years for permanent structures, inflation rate for electricity 3%, for oil 9%, and discount rate of 10%, material and labor increases 3% (NAVFAC INST 4100.6). For our computations of the electric energy cost we used the Philadelphia Electric Company rates.

Energy Charge Prices:

1.66¢ per KWH for the first 150 hours use of billing demand

1.27¢ per KWH for the next 150 hours use of billing demand but not more than 1,200,000 KWH

.91¢ per KWH for the next 100 hours use of billing demand but not more than 500,000 KWH

.77¢ per KWH for the additional use

Monthly Rate Table - Capacity Charge Prices:

Per Kw of billing demand:

$4.31 per KW for the first 25 KW

$2.70 per KW for the next 25 KW

$1.83 per KW for the next 450 KW

$1.66 per KW for the next 4,500 KW

5.3.3.2 Water Flow and Pump Horsepower (Base Building):

(1) Chilled Water Flow (20° Δt)

$$GPM = \frac{Tons \times 12{,}000\ BTUH/Ton}{8.33\ lb./gal. \times 60\ Min./Hr. \times 20^\circ \Delta t} = 1.2 \times tons$$

$$Pump\ BHP = \frac{GPM \times 8.33\ lb./gal. \times Head\ in\ Ft.\ (H_2O)}{33{,}000\ Ft.\ lb./Min. \times 0.55\ (Efficiency)}$$

Pump KW = BHP x 0.746 KW/HP = 0.0246 x Tons

(60' pump head is assumed.) Frictional head for other runs is taken as proportional to square of the flow.

(2) Condenser Water Flow (10° Δt)

GPM = Tons x 3 GPM/Ton = 3 x Tons. Similarly, Pump KW = 0.0683 x Tons (50' head is assumed.) Frictional head for other runs is taken as proportional to square of the flow.

(3) Hot Water Pumps (20° Δt). Radiation Pump KW:

$$\frac{MBH\ (Trans) \times 1000 \times 8.33 \times 60'\ (head) \times 0.746}{8.33\ lb./Gal. \times 60\ min./Hr. \times 20^\circ\ \Delta t \times 33{,}000 \times 0.55}$$

= 0.021 x MBH

Same value for reheat coils pump. For other runs revise frictional head proportional to the flow rate.

(4) Fan Energy (Base Building):

$$KW = \frac{CFM \times Static\ Pressure\ Inches\ (H_2O \times 0.746}{6350 \times 0.60\ (Efficiency)}$$

= 0.00098 x CFM

Based on 5.0" static pressure. Friction for other

runs proportional to square of flow. For variable volume allow 1.0" additional for high pressure system.

(5) Cooling Tower Fan (7-1/2 HP assumed)

KW = Horsepower x 0.746 = 5.6 KW

5.3.3.3 Holidays. The calendar year is to be 1975, which begins on a Wednesday, and the following 8 holidays will be observed: January 1 - New Year's Day, May 26 - Memorial Day, July 4 - Independence Day, September 1 - Labor Day, October 13 - Columbus Day, October 27 - Veterans Day, November 27 - Thanksgiving Day, and December 25 - Christmas.

5.3.3.4 Runs. The Following four (4) runs were made to see the affect of variation in the design parameters and systems:

(1) Run 1. Base building - Loads with glass exposed to north and south; constant volume with reheat, perimeter radiation, with enthalpy cycle. Reheat coils designed for 10° air temperature rise.

$U_w = 0.30$

$U_r = 0.18$

$U_{glass} = 1.13$, shading coefficient 0.55

54% Single glass (percent glass as shown on drawing)

(2) Run 2. Load calculations revising (1) to double glass with U_{glass} 0.65 and shading coefficient 0.51. This change reduces the energy consumption by 13%.

(3) Run 3. Load calculation with $U_w = 0.08$, $U_r = 0.05$, enthalpy cycle. This thermal conductance value corresponds to that required by DOD document 4270.1-M. This run has 11% less energy requirement when compared with Run 1.

(4) Run 4. Load calculations using exhaust-ventilation heat recovery wheels. No enthalpy cycle. This reduces energy usage by 1%. This low reduction in energy usage is due to lower outdoor air quantity of 2371 cubic feet per minute.

Table 5-1
Initial Investment
(Estimated HVAC Systems and Components)

	1E	2E	3E	4E
A. Central Chilled Water Plant @ $2,000/Ton constant volume reheat system and $1,675/ton for variable volume system (Air systems, cooling tower, heating coil, enthalpy control, piping, etc.)	$210,060	$203,580	$207,480	$203,000
B. Heating Hot water and humidification boiler, radiation	$ 32,080	$ 27,920	$ 26,620	$ 24,380
C. Insulation and Glazing Wall insulation	0	0	$ 3,680	0
Roof insulation	$ 5,070	$ 5,070	$ 25,340	$ 5,070
Glass - single @ $4.00/sq.ft. and double @ $6.50/sq.ft.	$ 17,470	$ 28,390	$ 17,470	$ 17,470
D. Miscellaneous Heat recovery wheels	-	-	-	$ 2,400
Total	$264,680	$264,960	$270,590	$252,320

Table 5-2
HECOL Load Summary for Existing Building (23,136 SQ.FT.)

Run No.	1E	2E	3E	4E
Peak Load (Hr/Month)	2pm/SEP	2pm/SEP	1pm/OCT	2pm/SEP
Lighting, MBH	255.0	255.0	255.0	255.0
Equipment, MBH	255.0	255.0	255.0	255.0
People, MBH (Total)	208.8	208.8	208.8	208.8
Solar, MBH	275.0	255.0	330.6	275.0
Transmission, MBH	87.3	68.4	16.2	87.3
Infilt. & Vent., MBH (Total)	176.1	176.1	176.1	176.1
Supply CFM	50,529	48,749	48,516	50,529
Total Tonnage	105.03	101.79	103.74	105.03
Winter Ventilation, MBH	138.3	138.3	138.3	138.3
Winter Trans. & Infilt., MBH	566.8	453.6	430.7	566.8

Table 5-3
Summary of Annual Energy Consumption For Existing Building

Run No.	1	2	3	4
Electricity, KWH	753,189	731,957	729,130	852,037
Electrical Cost	$20,918	$20,355	$20,309	$22,637
Oil, Gallons	24,736	19,685	20,773	21,885
Oil Cost	$ 8,905	$ 7,087	$ 7,478	$ 7,879
Total Energy Cost	$29,823	$27,441	$27,787	$30,515

Table 5-4
Summary of Energy Analysis

	1E	2E	3E	4E
1. Humidification Load MBH	482	494	430	0
2. Initial Investment Cost HVAC Systems $	264,680	264,960	270,590	252,320
3. Total Present Worth of Owning and Operating Cost	980,410	937,066	949,635	968,042
4. Selection Prference Based on 3	4	1	2	3
5. BTU/Yr./Sq.Ft. at the Building Bounday	261,861	227,946	234,160	259,068
6. Selection Preference Based on 5	4	1	2	3
7. BTU/Yr./Sq.Ft. Based on Raw Energy to Allow Utility Plant Efficiency (30%)	521,117	479,893	485,134	552,348
8. Selection Preference Based on 7	3	1	2	4

NOTE: Item 5 = $\frac{\text{KWH} \times 3413 + \text{Gals.} \times 141{,}000}{23{,}136}$ Item 7 = $\frac{\frac{\text{KWH} \times 3413}{0.3} + \text{Gals.} \times 141{,}000}{23{,}136}$

KLING-LINDQUIST * NAVFAC ENERGY STUDY * RUN NO. 1 * JOB NO. 1335-00 * CARPENTER ZONE ALL

* ROOM * MEASURE	ROOM AREA SF	ROOM VOL CF	WALL AREA SF	GLASS AREA SF	NET WALL AREA SF	PCT GLASS TO WALL
	23136.	198558.	8164.	4368.	3796.	53.50
* SUMMER * SENSIBLE	SENSIBLE HEAT BTUH	SUPPLY AIR CFM	DEHUMID AIR CFM	FRESH AIR CFM	SUPPLY AIR RATE CFM/SF	SUPPLY AIR CHANGE MIN
	1012303.	(46866) 50,529 (Undiversified)	40753.	2371.	2.03	4.24
	FRESH AIR CHANGE MIN	SENSIBLE HEAT TONS	SENS HEAT RATE SF/TON	FRESH AIR HEAT BTUH		
	83.74	84.36	274.26	33289.00		
		GLASS HEAT BTUH	WALL HEAT BTUH	ROOF HEAT BTUH	FLOOR HEAT BTUH	
		44422.56	5166.69	37708.26	.00	
		PARTITION HEAT BTUH	LIGHT HEAT BTUH	MISCEL. HEAT BTUH	PEOPLE HEAT BTUH	
		3267.40	254866.17	254966.85	116000.00	
* SUMMER * LATENT	LATENT HEAT BTUH	LATENT HEAT TONS	FRESH AIR HEAT BTUH			
	134257.	11.19	80456.			
* SUMMER * TOTAL	TOTAL S+L HEAT BTUH	SENSIBLE HEAT RATIO	FRESH AIR PEN BTUH	FRESH AIR PEN TONS	TOT S+L+FAP HEAT TONS	TOT S+L+FAP RATE SF/TON
	1146560.	.88	113745.	9.48	105.03	220.29
* SUMMER * SUBTOTAL	SKIN HEAT LOAD BTUH	SOLAR HEAT ONLY BTUH	NUMBER OF PEOPLE			
	362281.	274983.	464.			
* WINTER * HEAT LOAD	TRANSM HEAT BTUH	VENTIL HEAT BTUH	TOTAL HEAT BTUH			
	566820.	138277.	705097.			

NUMBER OF ROOMS IN BUILDING	ORIGINAL	39
	DUPLICATE	0
	TOTAL	39

EQUIPMENT ENERGY CONSUMPTION AND OPERATING DATA FOR

RUNIE NAVFAC ENERGY ANALYSIS.CONSTANT VOL.WITH REHEAT.PERIMETER RAD.N-S SING.GL

SYSTEM 1 CONSTANT VOLUME WITH REHEAT.PERIMETER RADIATION N-S SINGLE GLASS EXISTNG BLDG

FUEL AND POWER CONSUMPTION

SYS	GAS USAGE MCF	PEAK DAY GAS MCF	ELECTRIC USAGE KWH	PEAK ELEC DEMAND (30 MIN)	AUXILIARY FUEL USAGE
** JAN **					
1	0.	0.	53015.	195.	4120.
** FEB **					
1	0.	0.	48121.	219.	4017.
** MAR **					
1	0.	0.	55431.	316.	2725.
** APR **					
1	0.	0.	61686.	316.	1638.
** MAY **					
1	0.	0.	69027.	313.	1749.
** JUN **					
1	0.	0.	72845.	315.	1484.
** JUL **					
1	0.	0.	77660.	315.	1284.
** AUG **					
1	0.	0.	74572.	312.	124.
** SEP **					
1	0.	0.	71927.	313.	240.
** OCT **					
1	0.	0.	61702.	314.	1513.
** NOV **					
1	0.	0.	53469.	311.	1959.
** DEC **					
1	0.	0.	53733.	298.	3884.
** ANN **					
1	0.	0.	753189.	316.	24736.

MONTHLY AND ANNUAL UTILITY COST FOR

RUN1E CONSTANT VOL W.REHEAT PER.RADIATION SINGLE GLASS N-S

	ELECTRIC COST, $	AVER RATE C/KWH	UNIT COST C/SQFT	GAS COST, $	AVER RATE C/MCF	UNIT COST C/SQFT	AUX FUEL COST, $	AVER RATE C/UNIT	UNIT COST C/SQFT	CHILLED WATER COST, $	AVER RATE C/TNHR	UNIT COST C/SQFT	STEAM OR HOT WATER COST, $	AVER RATE $/MMB	UNIT COST C/SQFT
SYSTEM 1	RN1E CONSTANT VOL W/REHT														
JAN	1569.	2.959	.678	0.	.00	.000	1483.	36.00	.641						
FEB	1478.	3.071	.639	0.	.00	.000	1446.	36.00	.625						
MAR	1616.	2.915	.698	0.	.00	.000	981.	36.00	.424						
APR	1728.	2.801	.747	0.	.00	.000	590.	36.00	.255						
MAY	1855.	2.687	.802	0.	.00	.000	630.	36.00	.272						
JUN	1923.	2.639	.831	0.	.00	.000	534.	36.00	.231						
JUL	2009.	2.586	.868	0.	.00	.000	462.	36.00	.200						
AUG	1954.	2.620	.844	0.	.00	.000	45.	36.00	.019						
SEP	1906.	2.650	.824	0.	.00	.000	86.	36.00	.037						
OCT	1724.	2.794	.745	0.	.00	.000	545.	36.00	.235						
NOV	1577.	2.949	.682	0.	.00	.000	705.	36.00	.305						
DEC	1581.	2.943	.684	0.	.00	.000	1398.	36.00	.604						
ANN	20918.	2.777	9.041	0.	.00	.000	8905.	36.00	3.849						

TOTAL UTILITY COST

NO	NAME	$
1	RN1E CONSTANT VOL W/REHT	29823.

KLING-LINDQUIST * NAVFAC ENERGY STUDY * RUN NO. 2 * JOB NO. 1335-00 * CARPENTER ZONE ALL

* ROOM * MEASURE	ROOM AREA SF 23136.	ROOM VOL CF 198558.	WALL AREA SF 8164.	GLASS AREA SF 4368.	NET WALL AREA SF 3796.	PCT GLASS TO WALL 53.50
* SUMMER * SENSIBLE	SENSIBLE HEAT BTUH 973436.	SUPPLY AIR CFM (45066) 48,749 (Undiversified)	DEHUMID AIR CFM 39188.	FRESH AIR CFM 2371.	SUPPLY AIR RATE CFM/SF 1.95	SUPPLY AIR CHANGE MIN 4.41
	FRESH AIR CHANGE MIN 83.74	SENSIBLE HEAT TONS 81.12	SENS HEAT RATE SF/TON 285.21	FRESH AIR HEAT BTUH 33289.00		
		GLASS HEAT BTUH 25552.80	WALL HEAT BTUH 5166.69	ROOF HEAT BTUH 37708.26	FLOOR HEAT BTUH .00	
		PARTITION HEAT BTUH 3267.40	LIGHT HEAT BTUH 254866.17	MISCEL. HEAT BTUH 254966.85	PEOPLE HEAT BTUH 116000.00	
* SUMMER * LATENT	LATENT HEAT BTUH 134257.	LATENT HEAT TONS 11.19	FRESH AIR HEAT BTUH 80456.			
* SUMMER * TOTAL	TOTAL S+L HEAT BTUH 1107693.	SENSIBLE HEAT RATIO .88	FRESH AIR PEN BTUH 113745.	FRESH AIR PEN TONS 9.48	TOT S+L+FAP HEAT TONS 101.79	TOT S+L+FAP RATE SF/TON 227.30
* SUMMER * SUBTOTAL	SKIN HEAT LOAD BTUH 325412.	SOLAR HEAT ONLY BTUH 254984.	NUMBER OF PEOPLE 464.			
* WINTER * HEAT LOAD	TRANSM HEAT BTUH 453605.	VENTIL HEAT BTUH 138277.	TOTAL HEAT BTUH 591882.			

NUMBER OF ROOMS IN BUILDING ORIGINAL 39
DUPLICATE 0
TOTAL 39

EQUIPMENT ENERGY CONSUMPTION AND OPERATING DATA FOR

NUM2E NAVFAC ENERGY ANALYSIS,CONSTANT VOL.WITH REHEAT,PERIMETER RAD.N=S INSL.GL

SYSTEM 1 CONSTANT VOLUME WITH REHEAT,PERIMETER RADIATION N=S INSULAT GLASS

FUEL AND POWER CONSUMPTION

SYS	GAS USAGE MCF	PEAK DAY GAS MCF	ELECTRIC USAGE KWH	PEAK ELEC DEMAND (30 MIN)	AUXILIARY FUEL USAGE
** JAN **					
1	0.	0.	51373.	189.	3257.
** FEB **					
1	0.	0.	46648.	232.	3174.
** MAR **					
1	0.	0.	53750.	305.	2183.
** APR **					
1	0.	0.	59911.	310.	1286.
** MAY **					
1	0.	0.	67814.	301.	1417.
** JUN **					
1	0.	0.	71015.	303.	1203.
** JUL **					
1	0.	0.	75064.	303.	1047.
** AUG **					
1	0.	0.	72091.	300.	122.
** SEP **					
1	0.	0.	69696.	301.	208.
** OCT **					
1	0.	0.	60212.	310.	1194.
** NOV **					
1	0.	0.	52186.	299.	1561.
** DEC **					
1	0.	0.	52198.	293.	3033.
** ANN **					
1	0.	0.	731957.	310.	19685.

MONTHLY AND ANNUAL UTILITY COST FOR

RW2E CONSTANT VOL W.REHEAT.PER.RADIATION INSULATING GLASS

	ELECTRIC COST, $	AVER RATE C/KWH	UNIT COST C/SQFT	GAS COST, $	AVER RATE C/MCF	UNIT COST C/SQFT	AUX FUEL COST, $	AVER RATE C/UNIT	UNIT COST C/SQFT	CHILLED WATER COST, $	AVER RATE C/TNHR	UNIT COST C/SQFT	STEAM OR HOT WATER COST, $	AVER RATE $/MMB	UNIT COST C/SQFT
SYSTEM 1 RW2E CONSTANT VOL W/REHT															
JAN	1519.	2.957	6.566	0.	.00	.000	1175.	36.00	5.068						
FEB	1432.	3.079	6.149	0.	.00	.000	1143.	36.00	4.939						
MAR	1570.	2.921	6.786	0.	.00	.000	786.	36.00	3.397						
APR	1701.	2.659	7.355	0.	.00	.000	465.	36.00	2.001						
MAY	1812.	2.673	7.834	0.	.00	.000	510.	36.00	2.205						
JUN	1870.	2.635	[illegible]	0.	.00	.000	433.	36.00	1.872						
JUL	1942.	2.587	6.595	0.	.00	.000	377.	36.00	1.629						
AUG	1889.	2.620	6.164	0.	.00	.000	44.	36.00	.190						
SEP	1846.	2.649	7.979	0.	.00	.000	75.	36.00	.324						
OCT	1706.	2.634	7.376	0.	.00	.000	430.	36.00	1.858						
NOV	1534.	2.939	6.626	0.	.00	.000	562.	36.00	2.429						
DEC	[illegible]	2.958	6.629	0.	.00	.000	1092.	36.00	4.719						
ANN	20355.	2.781	87.978	0.	.00	.000	7087.	36.00	30.630						

TOTAL UTILITY COST

NO	NAME	$
1	RW2E CONSTANT VOL W/REHT	27441.

KLING-LINDQUIST * NAVFAC ENERGY STUDY * RUN NO. 3 * JOB NO. 1335-00 * CARPENTER ZONE ALL

* ROOM * MEASURE	ROOM AREA SF	ROOM VOL CF	WALL AREA SF	GLASS AREA SF	NET WALL AREA SF	PCT GLASS TO WALL
	23136.	198558.	8164.	4368.	3796.	53.50
* SUMMER * SENSIBLE	SENSIBLE HEAT BTUH	SUPPLY AIR CFM	DEHUMID AIR CFM	FRESH AIR CFM	SUPPLY AIR RATE CFM/SF	SUPPLY AIR CHANGE MIN
	996885.	(46152.) 48,516 (Undiversified)	40132.	2371.	1.99	4.30
	FRESH AIR CHANGE MIN	SENSIBLE HEAT TONS	SENS HEAT RATE SF/TON	FRESH AIR HEAT BTUH		
	83.74	83.07	278.50	33289.00		
		GLASS HEAT BTUH	WALL HEAT BTUH	ROOF HEAT BTUH	FLOOR HEAT BTUH	
		14807.52	-541.47	1970.29	.00	
		PARTITION HEAT BTUH	LIGHT HEAT BTUH	MISCEL. HEAT BTUH	PEOPLE HEAT BTUH	
		3267.40	254866.17	254966.85	116000.00	
* SUMMER * LATENT	LATENT HEAT BTUH	LATENT HEAT TONS	FRESH AIR HEAT BTUH			
	134257.	11.19	80456.			
* SUMMER * TOTAL	TOTAL S+L HEAT BTUH	SENSIBLE HEAT RATIO	FRESH AIR PEN BTUH	FRESH AIR PEN TONS	TOT S+L+FAP HEAT TONS	TOT S+L+FAP RATE SF/TON
	1131140.	.88	113745.	9.48	103.74	223.02
* SUMMER * SUBTOTAL	SKIN HEAT LOAD BTUH	SOLAR HEAT ONLY BTUH	NUMBER OF PEOPLE			
	346862.	330626.	464.			
* WINTER * HEAT LOAD	TRANSM HEAT BTUH	VENTIL HEAT BTUH	TOTAL HEAT BTUH			
	430704.	138277.	568981.			

NUMBER OF ROOMS IN BUILDING ORIGINAL 39
DUPLICATE 0
TOTAL 39

EQUIPMENT ENERGY CONSUMPTION AND OPERATING DATA FOR

RUN3E NAVFAC ENERGY ANALYSIS,CONSTANT VOL,REHT,RAD,UWALL .08 UROOF .05

SYSTEM 1 CONSTANT VOLUME WITH REHEAT,PERIMETER RADIATION N=8 SINGLE GLASS

FUEL AND POWER CONSUMPTION

SYS	GAS USAGE MCF	PEAK DAY GAS MCF	ELECTRIC USAGE KWH	PEAK ELEC DEMAND (30 MIN)	AUXILIARY FUEL USAGE
** JAN **					
1	0.	0.	51096.	188.	3225.
** FEB **					
1	0.	0.	46342.	211.	3113.
** MAR **					
1	0.	0.	53119.	307.	2338.
** APR **					
1	0.	0.	59260.	308.	1821.
** MAY **					
1	0.	0.	67332.	305.	1415.
** JUN **					
1	0.	0.	71059.	306.	1258.
** JUL **					
1	0.	0.	75757.	306.	1156.
** AUG **					
1	0.	0.	72973.	305.	178.
** SEP **					
1	0.	0.	70228.	305.	347.
** OCT **					
1	0.	0.	59015.	308.	1459.
** NOV **					
1	0.	0.	51156.	292.	1715.
** DEC **					
1	0.	0.	51834.	288.	2947.
** ANN **					
1	0.	0.	729130.	308.	20773.

MONTHLY AND ANNUAL UTILITY COST FOR

RUN3E CONS.VOL.REHT.PER.RAD.REVISED WALL.ROOF FACTOR

	ELECTRIC COST, $	AVER RATE C/KWH	UNIT COST C/SQFT	GAS COST, $	AVER RATE C/MCF	UNIT COST C/SQFT	AUX FUEL COST, $	AVER RATE C/UNIT	UNIT COST C/SQFT	CHILLED WATER COST, $	AVER RATE C/TNHR	UNIT COST C/SQFT	STEAM OR HOT WATER COST, $	AVER RATE $/MMB	UNIT COST C/SQFT
SYSTEM 1	RN3E CONSTANT VOL W/REHT														
JAN	1518.	2.974	6.563	0.	.00	.000	1161.	36.00	5.018						
FEB	1430.	3.087	6.183	0.	.00	.000	1121.	36.00	4.844						
MAR	1559.	2.936	6.741	0.	.00	.000	842.	36.00	3.638						
APR	1665.	2.809	7.196	0.	.00	.000	584.	36.00	2.522						
MAY	1809.	2.687	7.819	0.	.00	.000	509.	36.00	2.202						
JUN	1876.	2.639	8.106	0.	.00	.000	453.	36.00	1.957						
JUL	1959.	2.586	8.469	0.	.00	.000	416.	36.00	1.799						
AUG	1910.	2.617	8.254	0.	.00	.000	64.	36.00	.277						
SEP	1861.	2.649	8.042	0.	.00	.000	125.	36.00	.540						
OCT	1669.	2.828	7.214	0.	.00	.000	525.	36.00	2.270						
NOV	1520.	2.972	6.571	0.	.00	.000	617.	36.00	2.669						
DEC	1532.	2.956	6.623	0.	.00	.000	1061.	36.00	4.586						
ANN	[illegible]	2.785	87.781	0.	.00	.000	7478.	36.00	32.322						

TOTAL UTILITY COST

NO	NAME	$
1	RN3E CONSTANT VOL W/REHT	27787.

KLING-LINDQUIST * NAVFAC ENERGY STUDY * RUN NO. 1 * JOB NO. 1335-00 * CARPENTER ZONE ALL

* ROOM * MEASURE	ROOM AREA SF	ROOM VOL CF	WALL AREA SF	GLASS AREA SF	NET WALL AREA SF	PCT GLASS TO WALL
	23136.	198558.	8164.	4368.	3796.	53.50
* SUMMER * SENSIBLE	SENSIBLE HEAT BTUH	SUPPLY AIR CFM	DEHUMID AIR CFM	FRESH AIR CFM	SUPPLY AIR RATE CFM/SF	SUPPLY AIR CHANGE MIN
	1012303.	(46866) 50529 (Undiversified)	40753.	2371.	2.03	4.24
	FRESH AIR CHANGE MIN	SENSIBLE HEAT TONS	SENS HEAT RATE SF/TON	FRESH AIR HEAT BTUH		
	83.74	84.36	274.26	53289.00		
		GLASS HEAT BTUH	WALL HEAT BTUH	ROOF HEAT BTUH	FLOOR HEAT BTUH	
		44422.56	5166.69	37708.26	.00	
		PARTITION HEAT BTUH	LIGHT HEAT BTUH	MISCEL. HEAT BTUH	PEOPLE HEAT BTUH	
		3267.40	254866.17	254966.85	116000.00	
* SUMMER * LATENT	LATENT HEAT BTUH	LATENT HEAT TONS	FRESH AIR HEAT BTUH			
	134257.	11.19	80456.			
* SUMMER * TOTAL	TOTAL S+L HEAT BTUH	SENSIBLE HEAT RATIO	FRESH AIR PEN BTUH	FRESH AIR PEN TONS	TOT S+L+FAP HEAT TONS	TOT S+L+FAP RATE SF/TON
	1146560.	.88	113745.	9.48	105.03	220.29
* SUMMER * SUBTOTAL	SKIN HEAT LOAD BTUH	SOLAR HEAT ONLY BTUH	NUMBER OF PEOPLE			
	362281.	274983.	464.			
* WINTER * HEAT LOAD	TRANSM HEAT BTUH	VENTIL HEAT BTUH	TOTAL HEAT BTUH			
	566820.	138277.	705097.			

NUMBER OF ROOMS IN BUILDING	ORIGINAL	39
	DUPLICATE	0
	TOTAL	39

EQUIPMENT ENERGY CONSUMPTION AND OPERATING DATA FOR

NUNAE NAVFAC ENERGY ANALYSIS CONSTANT VOL WITH REHEAT HEAT RECOVERY WHEELS

SYSTEM 1 CONSTANT VOLUME WITH REHEAT.PERIMETER RADIATION SINGLE GLASS HEAT REC.WHEELS.

FUEL AND POWER CONSUMPTION

SYS	GAS USAGE MCF	PEAK DAY GAS MCF	ELECTRIC USAGE KWH	PEAK ELEC DEMAND (30 MIN)	AUXILIARY FUEL USAGE
** JAN **					
1	0.	0.	67683.	281.	3597.
** FEB **					
1	0.	0.	64295.	307.	3432.
** MAR **					
1	0.	0.	73681.	310.	2337.
** APR **					
1	0.	0.	75841.	310.	1394.
** MAY **					
1	0.	0.	70910.	311.	1522.
** JUN **					
1	0.	0.	72415.	313.	1315.
** JUL **					
1	0.	0.	77240.	313.	1219.
** AUG **					
1	0.	0.	74620.	313.	124.
** SEP **					
1	0.	0.	73925.	313.	221.
** OCT **					
1	0.	0.	72869.	310.	1396.
** NOV **					
1	0.	0.	62934.	306.	1856.
** DEC **					
1	0.	0.	65625.	296.	3472.
** ANN **					
1	0.	0.	852037.	313.	21885.

MONTHLY AND ANNUAL UTILITY COST FOR

RUN4E CONS.VOL REHT.RAD.HEAT.RECOVERY WHEELS

	ELECTRIC COST, $	AVER RATE C/KWH	UNIT COST C/SQFT	GAS COST, $	AVER RATE C/MCF	UNIT COST C/SQFT	AUX FUEL COST, $	AVER RATE C/UNIT	UNIT COST C/SQFT	CHILLED WATER COST, $	AVER RATE C/TNHR	UNIT COST C/SQFT	STEAM OR HOT WATER COST, $	AVER RATE $/MMB	UNIT COST C/SQFT
SYSTEM 1 RN4E CONSTANT VOL W/REHT															
JAN	1627.	2.700	.000	0.	.00	.000	1295.	36.00	.000						
FEB	1767.	2.748	.000	0.	.00	.000	1236.	36.00	.000						
MAR	1934.	2.625	.000	0.	.00	.000	841.	36.00	.000						
APR	1973.	2.601	.000	0.	.00	.000	592.	36.00	.000						
MAY	1885.	2.658	.000	0.	.00	.000	548.	36.00	.000						
JUN	1912.	2.640	.000	0.	.00	.000	473.	36.00	.000						
JUL	1996.	2.586	.000	0.	.00	.000	439.	36.00	.000						
AUG	1951.	2.615	.000	0.	.00	.000	45.	36.00	.000						
SEP	1939.	2.622	.000	0.	.00	.000	80.	36.00	.000						
OCT	1920.	2.634	.000	0.	.00	.000	503.	36.00	.000						
NOV	1742.	2.769	.000	0.	.00	.000	668.	36.00	.000						
DEC	1790.	2.728	.000	0.	.00	.000	1250.	36.00	.000						
ANN	22637.	2.657	.000	0.	.00	.000	7879.	36.00	.000						

TOTAL UTILITY COST

NO	NAME	$
1	RN4E CONSTANT VOL W/REHT	30515.

CHAPTER 6. ELECTRICAL SYSTEMS

6.1 LIGHTING DESIGN REQUIREMENTS. The design of interior, exterior and sports lighting shall be in accordance with fundamentals and recommendations of the IES Lighting Handbook, published by the Illuminating Engineering Society, subject to the modifications and clarifications for implementing these criteria as noted in paragraphs 6.2 and 6.3.

6.2 LIGHTING INTENSITIES FOR FACILITIES. Maintained lighting intensities shall be those specified in Tables 6-1, 6-2, 6-3 and 6-4. Lighting intensities for other occupancies shall conform to the intensities established in the current edition of the IES Lighting Handbook. The IES recommended intensities are the illuminations required for specific visual tasks, and may be provided by the general illumination in those areas where lower intensities are required. However, the IES recommended intensities are not necessarily to be considered as general illumination intensities for specific areas. The intensity of the general illumination for any area shall not exceed 75 footcandles maintained. If a higher intensity is required for a particular task, it will be achieved by supplementing the general illumination with localized (supplementary) lighting for the particular task, Figure 6-1. The ratios between general and supplementary (local) illumination shall be at least those recommended by IES. Supplementary lighting, where required, will normally be provided by the user of the facility. However, special power requirements for such supplementary lighting shall be established in the design phase.

(1) Environmental Factors. The finish and color of surrounding surfaces and the surfaces of equipment and furniture shall be selected to reduce glare, increase light utilization and obtain an acceptable brightness balance. Lighting equipment and layout shall be coordinated with other facilities to prevent interferences and to promote good appearance.

(2) Medical and Dental Facility Illumination. Lighting intensities for medical and dental facilities shall conform to the IES recommendations with the exceptions listed in Table 6-1 below:

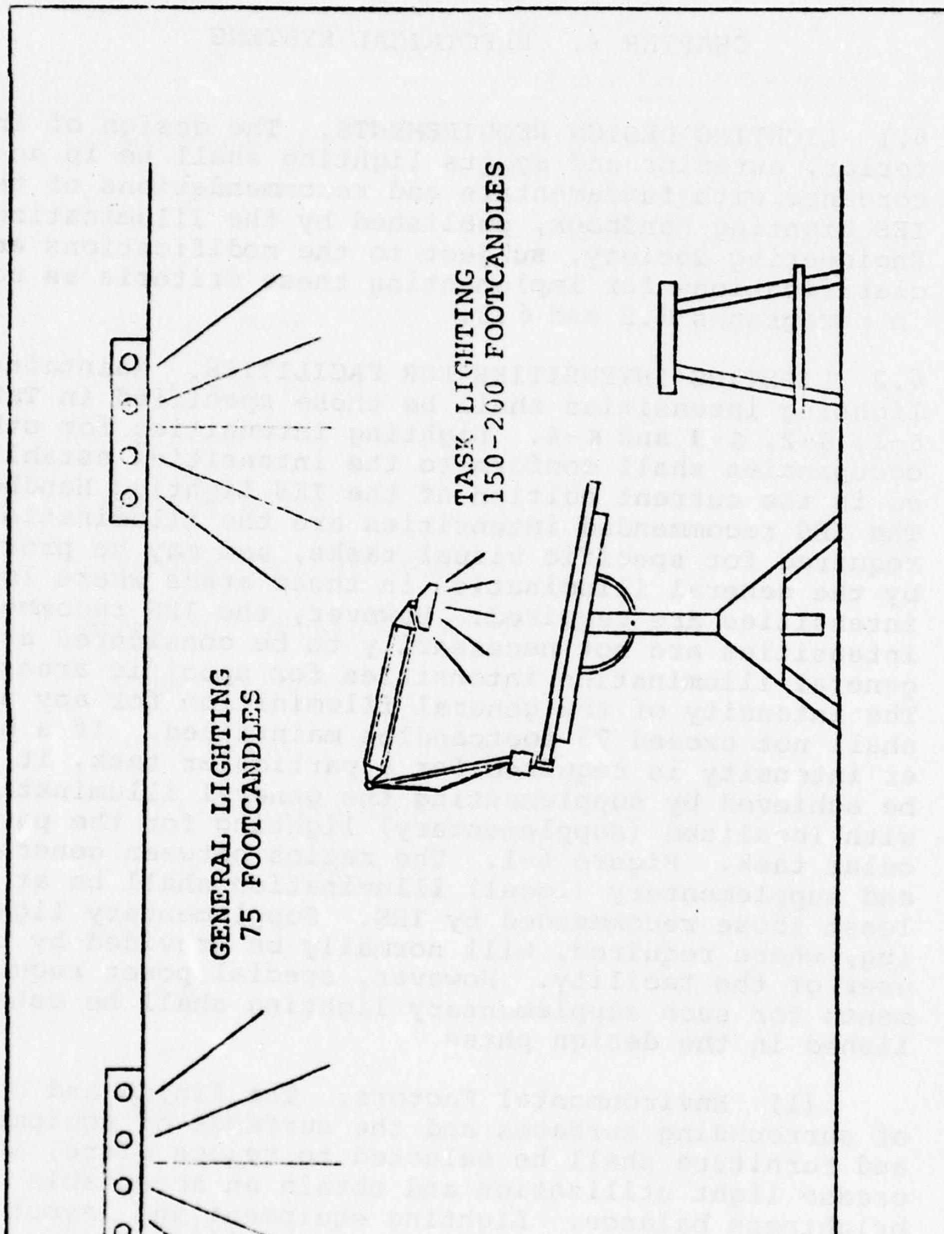


FIGURE 6-1

GENERAL VERSUS TASK LIGHTING

TABLE 6-1

Illumination in Medical and Dental Facilities

Area	Footcandle Intensity[1]
Anesthesia and Preparation Room	30
Control Sterile Supply	30
Fracture Room	50
Nurseries	30
Sewing Room	30
Exits, at Floor	5
Corridors	20

[1] Supplementary lighting, where needed for rooms and spaces in medical and dental facilities, will be prescribed by the Surgeon General of the using Service.

(3) Office Building Illumination. The general illumination level in office building spaces shall not exceed the rates listed in Table 6-2 as measures 2 feet 6 inches from the floor.

TABLE 6-2

Illumination in Office Buildings

Area	Footcandle Intensity
Accounting Rooms	75
Auditoriums	20
Cafeterias	25
Computer Rooms	50
Conference Rooms	30
Corridors	15
Drafting Rooms	75
Elevator Machine Rooms	15
Emergency Generator Rooms	15
Garage Entrance	30
Garage Driving and Parking	5
General Office Space	70
Janitor's Closets	5
Kitchens	70
Lobbies	15
Lounges	15
Mechanical Rooms	15
Parking Lots	0.5
Stairways	20
Storage Rooms	5
Switchgear Rooms	15
Toilets	20
Transformer Vaults	15

6.3 REMODELING. Special considerations should be given during remodeling and redecoration to lighter colors since light colored walls, ceilings, and carpets contribute to higher lighting values at lower wattage. Higher lighting levels may be achieved without extensive rewiring by any one or a combination of the following:

(a) Remove existing incandescent fixtures and replace with the more efficient fluorescent high intensity discharge or quartz type.

(b) Install a drop ceiling or lower the existing one if ceiling height exceeds 8'-0".

(c) Where the cost of installing or lowering an existing ceiling is prohibitive, pendant mount fixtures to decrease mounting height above the work plane.

(d) If practicable, repartition to larger office areas in preference to small cubicles, see Figure 6-2.

(e) Where large areas must be repartitioned into smaller cubicles, use light weight partitions, not over 6'-0" high, with translucent upper panels, wherever possible, in lieu of permanent floor to ceiling partitions, to minimize ceiling lighting and ventilation modifications.

(f) Remove and replace burned out, discolored and end blackened fluorescent lamps and establish a group relamping schedule consistent with the lamp life and hours-per-start.

(g) Establish and maintain a fixture cleaning schedule based upon the cleanliness of the environment.

(h) Where a ventilation and/or air conditioning system is installed, remove and replace or clean filters. If filtration is not provided, investigate the economic feasibility of adding same.

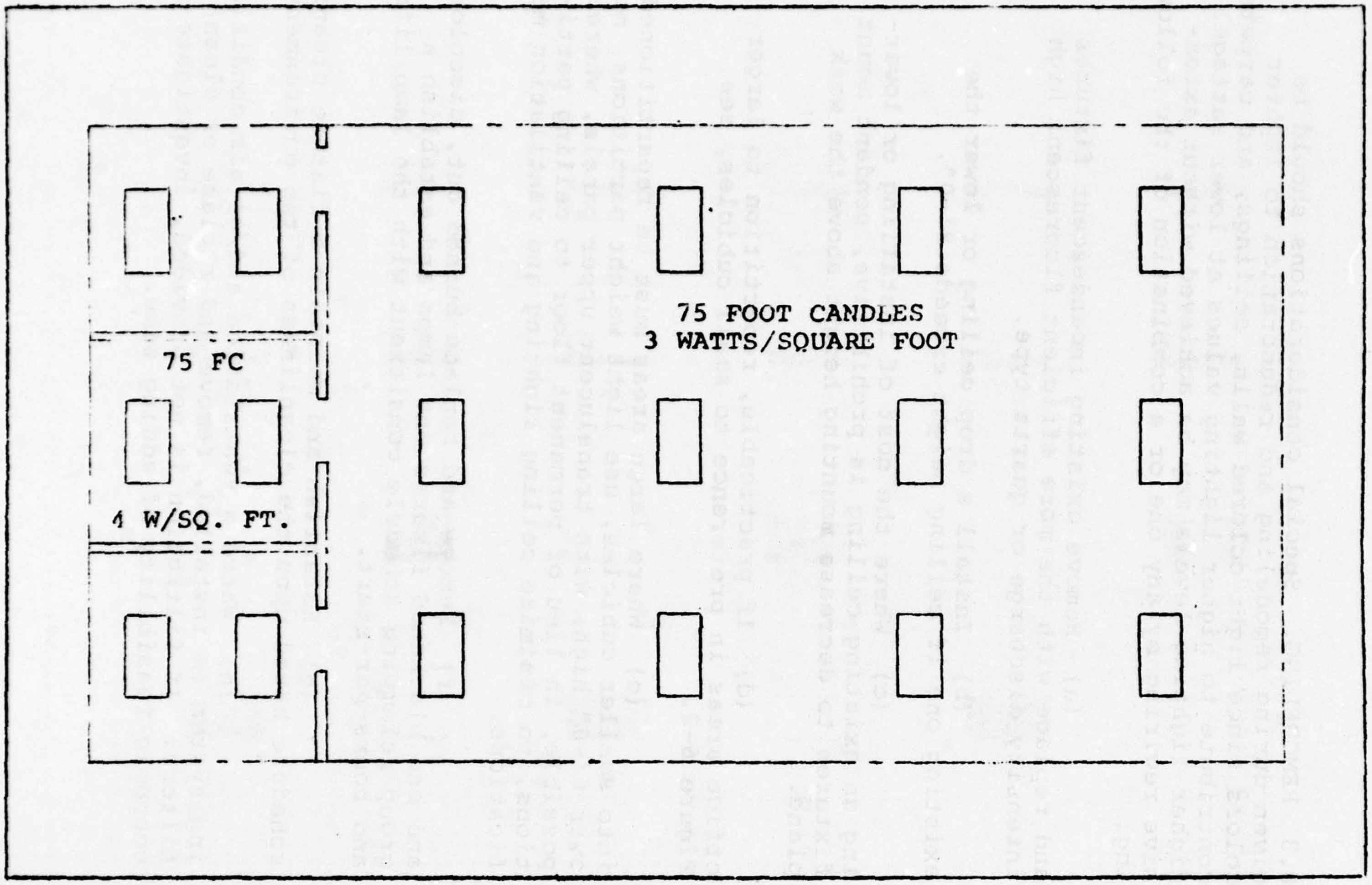


FIGURE 6-2

LARGE VERSUS SMALL AREA LIGHTING ADVANTAGES

6.3.1 Check for Conservation. Where increases in lighting levels are not necessary or a reduction can be tolerated, the lighting system should be checked for possible energy conservation. Remove burned out fluorescent lamps and disconnect ballasts. In a multi-lamp installation when both 40 watt fluorescent lamps are removed from alternate two-lamp fixtures, the series ballast in those fixtures will continue to consume energy. If only one lamp is removed, the other lamp will be extinguished but the fixture will continue to consume energy. Further, the lamp remaining in the fixture may suffer considerable damage and become inoperable in time. The ballast itself may also be damaged. If lamps are removed from a two-lamp rapid start ballast, both lamps must be taken out and the ballast should, if economically feasible, be disconnected. If the removal of lamps would result in too low a level of lighting, then consideration should be given to the use of lower wattage fluorescent lamps now being produced by the lamp manufacturers. Reduced wattage change kits are also available for mercury vapor systems. Further savings in energy consumption could also be accomplished through the selective control of area and lighting levels as follows:

(a) Inboard-outboard switching of 2 x 4 fluorescents allows two levels of light as needed, see Figure 6-3.

(b) Alternate switching of fixtures may accomplish the same result if fixture spacing is not excessive, see Figure 6-3.

(c) As much local switching as possible should be added so that unoccupied spaces may be switched off.

(d) Where panel switching is utilized rewiring should be done to control alternate rows of fixtures.

(e) Perimeter lighting adjacent to glass areas should be provided with switching to take advantage of supplemental daylight.

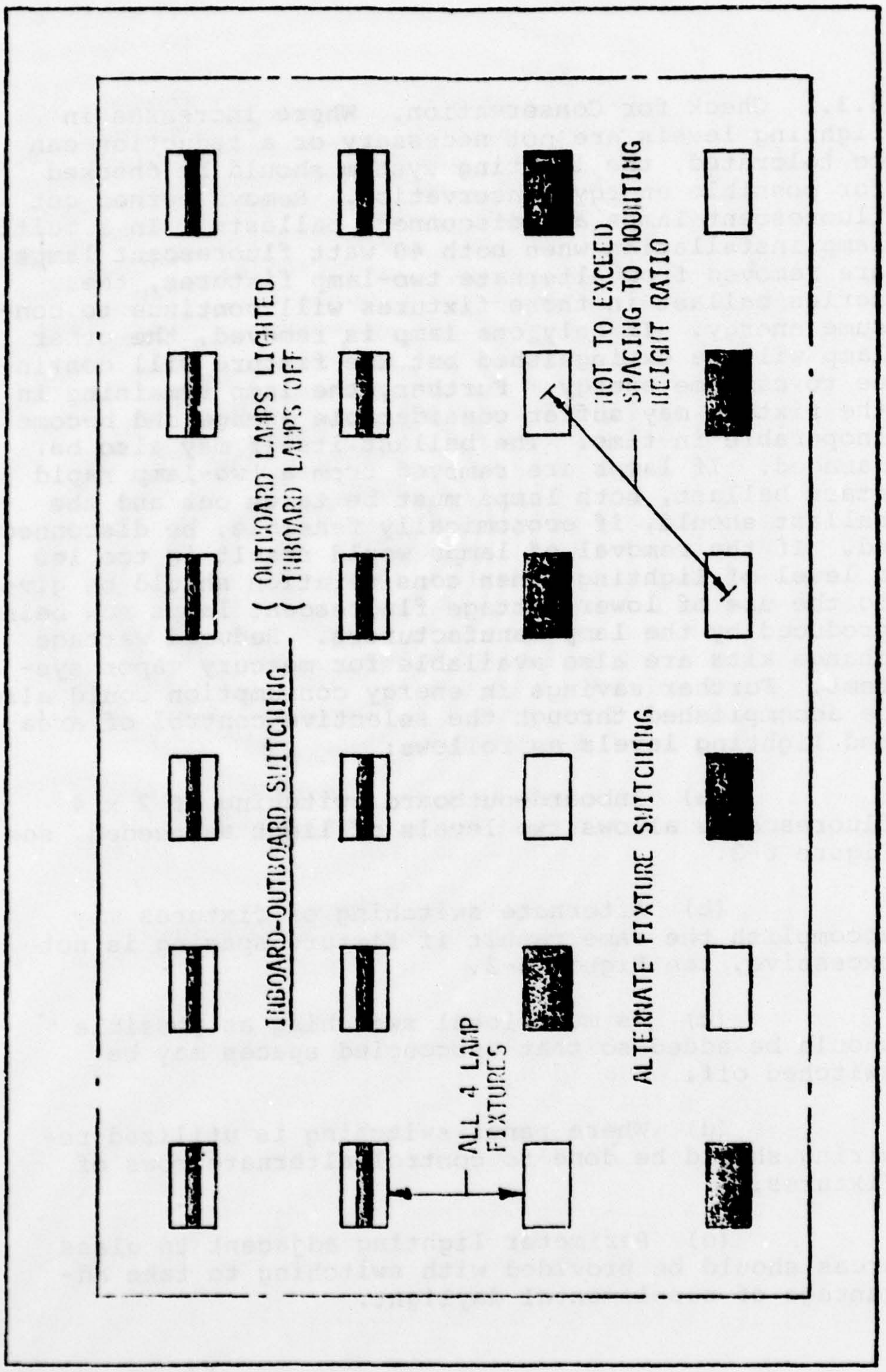


FIGURE 6-3

SELECTIVE SWITCHING SCHEMES

(f) The use of SCR dimming should be applied wherever economically feasible.

6.4 HANGAR ILLUMINATION. The general maintained illumination level of the high bay areas of hangers used for storage, deicing or cleaning of aircraft shall not exceed 30 footcandles. Illumination levels in maintenance hangers shall be in accordance with IES recommendations.

6.5 WAREHOUSE ILLUMINATION. The general illumination level in warehouses shall not exceed the rates listed in Table 6-3 as measured 4 feet from the floor.

TABLE 6-3

Illumination in Warehouses

Type of Warehousing	Footcandles Intensity
Inactive	5
Active-bulk	10*
Rack	20
Bin	5**
Mechanical Material Handling:	
a. Control Centers and Stations	30
b. Loading & Unloading Areas	20
c. Accumulation Conveyor Lines (unmanned)	10

* Main aisles may be lighted to 15 footcandles.

** Specialized lighting designed to illuminate the bins as required is to be provided by the user.

6.6 STREET, AREA AND SECURITY LIGHTING.

(1) Street and Area Lighting. Streets, parking areas, and walks should be lighted to provide safe vehicular and pedestrian circulation. Lights should be provided at street intersections, and between intersections at a spacing of approximately 150 to 200 feet. Walks not adjacent to streets, and steps in public walks, should be separately lighted.

(2) Security Lighting. Since most security lighting meets specialized requirements, such lighting should be redesigned, where possible, to use more efficient sources.

(3) Facade Floodlighting and tree and garden lighting should be eliminated. Street, parking lot, walkway and access road lighting should be revised to utilize efficient sources such as high pressure sodium, fluorescent or mercury vapor, see Figure 6-4. Wherever possible exterior lighting should be provided with automatic control as well as manual. The use of photocells only is not recommended. Time clocks or time clock-photocell combinations should be employed.

6.7 SYSTEM REVISIONS. The entire electrical distribution system should be reviewed to eliminate all possible sources of wasted electrical energy.

(1) Check Branch and Feeder Circuit Loading. If load exceeds 80% of the ampacity of the wiring, rewire or drop sufficient load to accomplish this reduction.

(2) Voltage Drop. Check the combined voltage drop in all feeders and branch circuits where it exceeds the permissible total voltage drop expressed as a percent of utilization voltage as set forth in the ANSI-CI standard of the latest revisions, remove and replace wiring of adequate size to meet these standards.

(3) Electrical Apparatus Maintenance. Inspect all electrical equipment, switchboards, transformers, starters, etc. for cleanliness. Clean as necessary and establish regular maintenance schedule for recleaning. Dust and dirt accumulation on electrical appara-

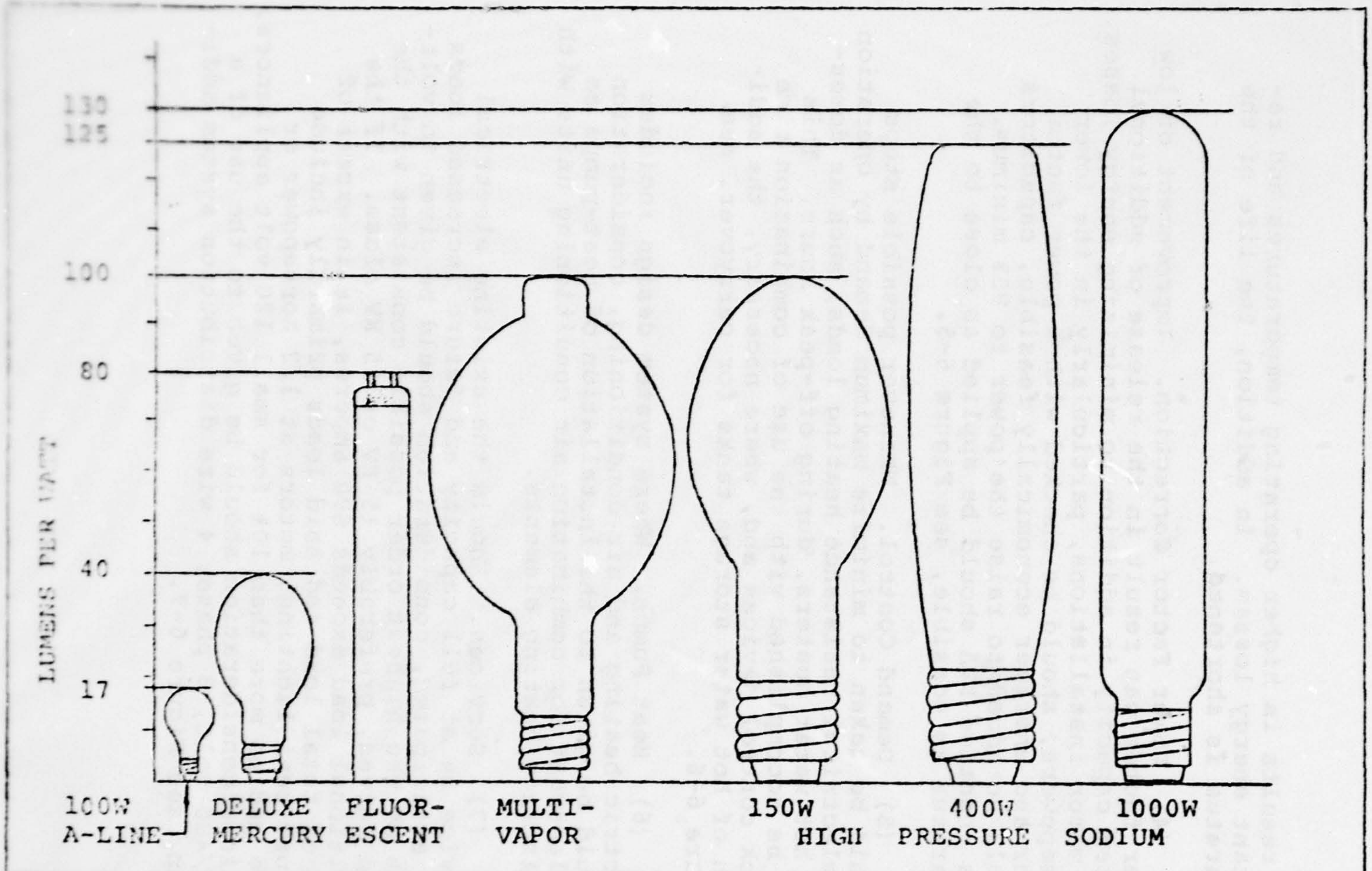


FIGURE 6-4

LIGHT OUTPUT IN LUMENS PER WATT FOR VARIOUS SOURCES

tus results in higher operating temperatures and resultant energy losses. In addition, the life of the apparatus is shortened.

(4) Power Factor Correction. Improvement of low power factor can result in the release of additional system capacity in addition to minimizing energy losses. All motor installations, particularly in the lower horsepowers, should be checked with a power factor meter and wherever economically feasible, capacitors should be added to raise the power to 90% minimum. This reactive KVA should be applied as close to the apparatus as possible, see Figure 6-5.

(5) Demand Control. Whenever possible steps should be taken to minimize maximum demand by operation of electrical resistance heating loads, such as domestic hot water heaters, during off-peak hours. This may be accomplished with the use of combination time clock control devices and, where necessary, the addition of hot water storage tanks for carryover, see Figure 6-6.

(6) Heat Pumps. Where system design includes electric heating and air conditioning, consideration should be given to the installation of heat-pumps as replacement for combination air conditioning units with resistance heating elements.

(7) Services. Should the existing electrical service be at full capacity and future increased loads are anticipated, consideration should be given to voltages of the highest order possible consistent with the load served, preferably 15 KV or 35 KV class. If the additional load exceeds 600 amperes, is in excess of 50% of total load and said loads primarily include fluorescent lighting, motors at 1/2 horsepower or more and no more than 10% for small 120 volt appliances, serious consideration should be given to the use of a 277/480 volt, 3 phase, 4 wire distribution system addition, see Figure 6-7.

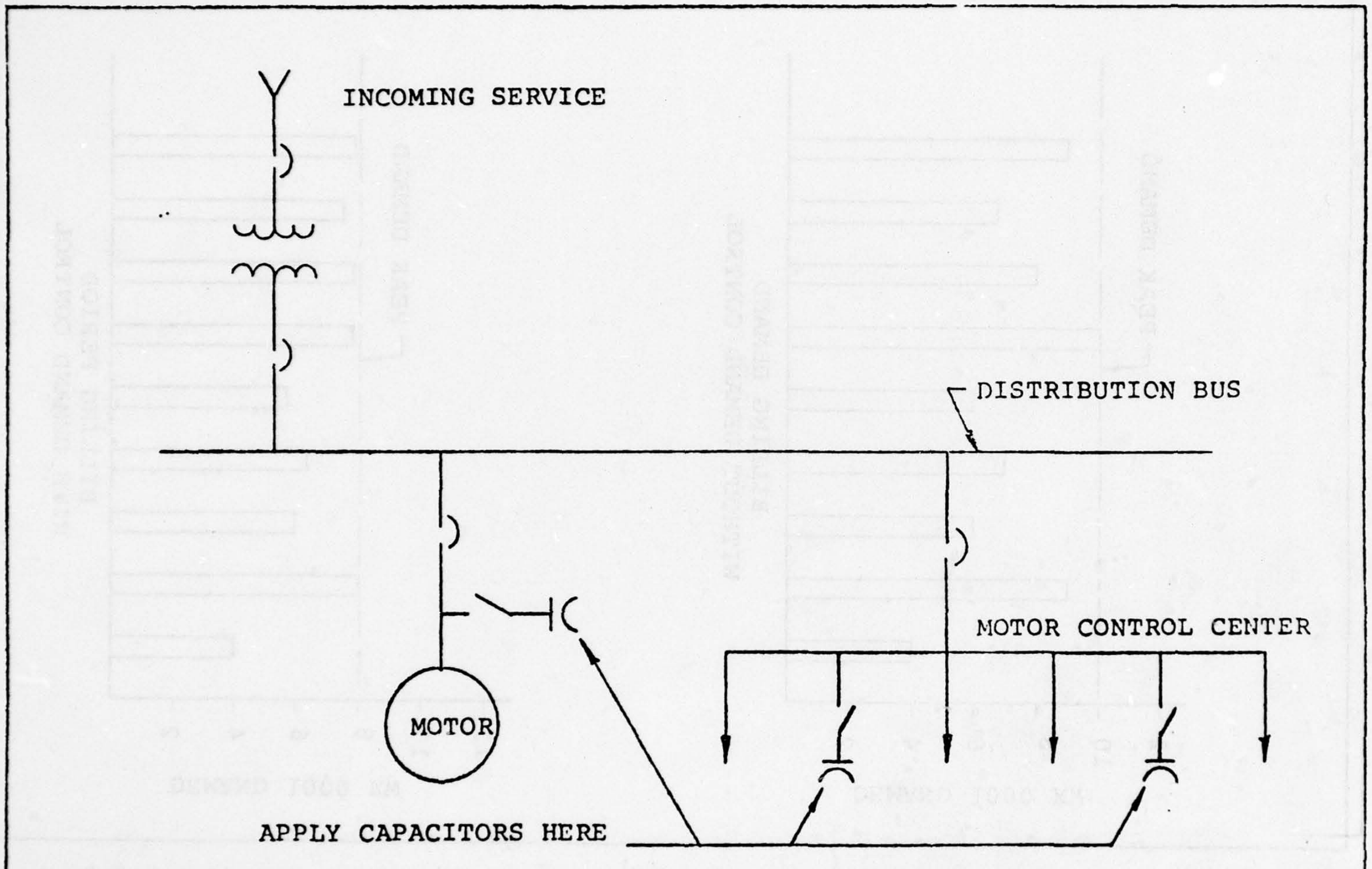


FIGURE 6-5

APPLICATION OF POWER FACTOR CORRECTION

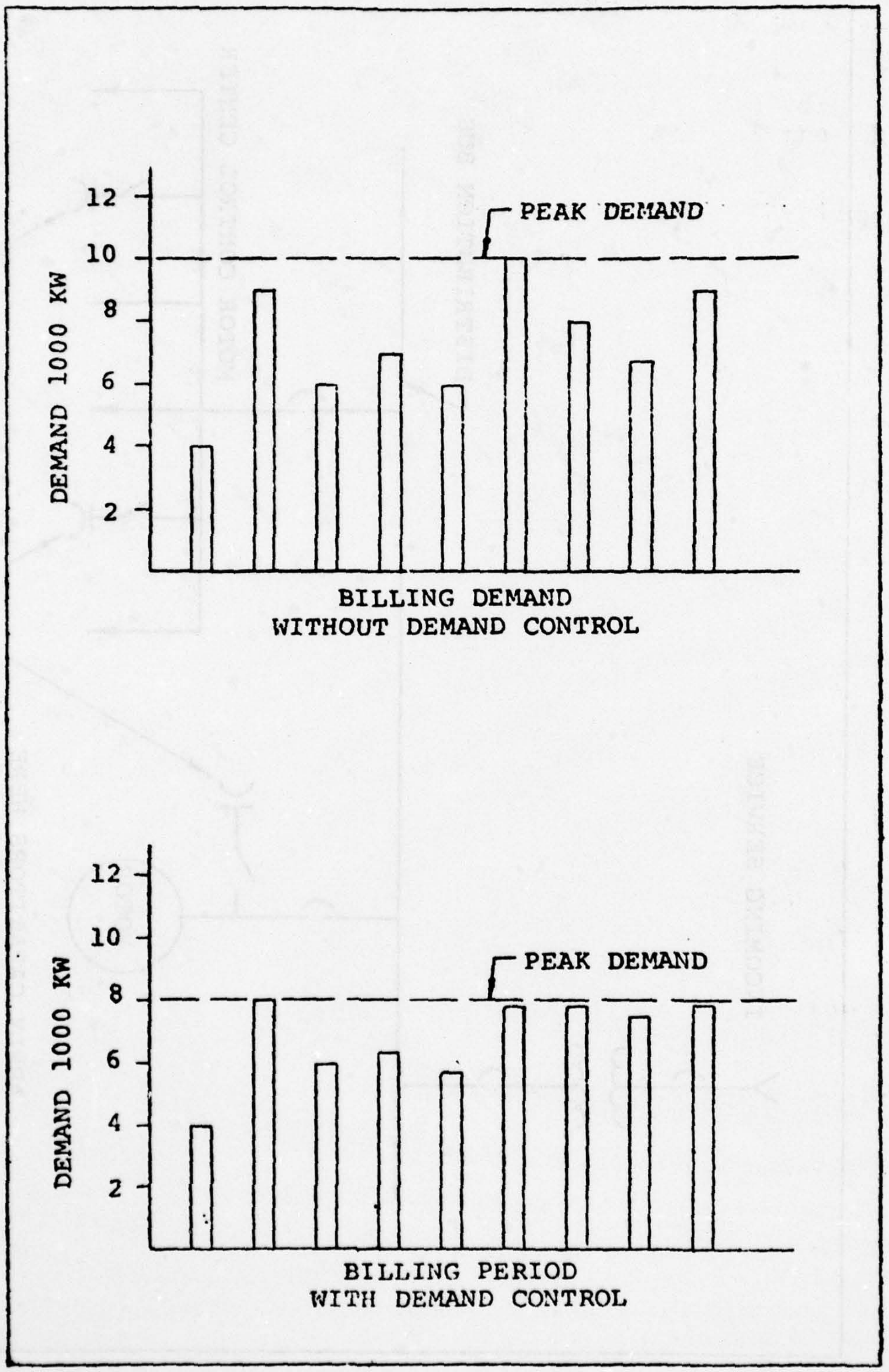


FIGURE 6-6

CONTROL OF PEAK DEMAND

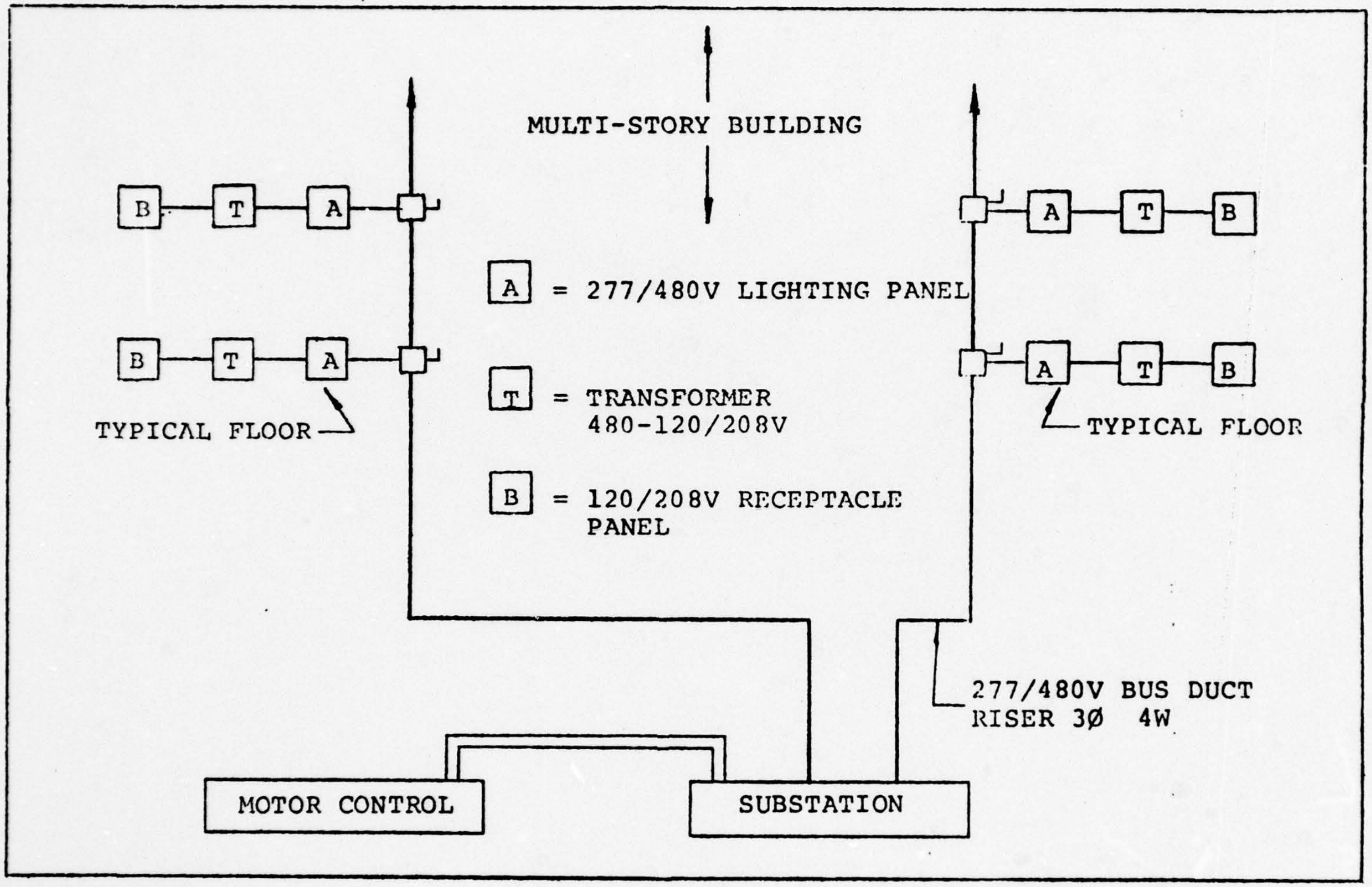


FIGURE 6-7

277/480 VOLT DISTRIBUTION SYSTEM

CHAPTER 7. OPERATION, MAINTENANCE
AND
BALANCING IN EXISTING BUILDINGS

7.1 EXISTING BUILDINGS. Operating methods and habits as they concern existing buildings are in many cases followed without particular regard to waste or conservation of the energy consumed. Prior to the past two or three years if the design was good and performance satisfactory, the efficient use of energy was not questioned. Most owners have recently become more aware of the increasing cost of building operation and are seeking ways to reduce these fixed costs. Where inattention to instructions or lack of interest has resulted in poor practice, this can be corrected by a review of the systems purpose and capability. At times minor changes to control systems are beneficial:

(1) One of these is the addition of a master control to close all minimum outside air intake dampers. Few older systems are provided with this feature. Many have individual switches but this means visiting each air apparatus twice each day. By closing the dampers during the period between startup and occupancy, the ventilation load is omitted temporarily.

(2) All sequential heater and damper controls should be checked and adjusted to prevent overlap. This is particularly important in bypass systems to avoid heating before the dehumidified damper reaches a minimum.

(3) On systems controlled for outdoor air refrigeration cycle, check and adjust maximum outside and return air dampers for tight closure.

(4) If main fans are constant temperature discharge with terminal reheat, do not control the fan discharge below the designed diffusion temperature at the outlets.

(5) On cooling cycle, if the space relative humidity drops below 50%, this indicated too low a dewpoint off the dehumidifier. Dewpoint control, if provided, may be raised slightly or chilled water temperature raised.

(6) If water temperatures in heating zones are controlled from outside, be sure water is scheduled at minimum temperature to provide comfort on the perimeter of the building.

(7) Do not run air systems overnight without refrigeration unless outside wet bulb temperature is below maintained interior wet bulb.

(8) Do not run toilet or other exhaust systems overnight when main systems are shut down.

(9) The building systems were designed to perform with windows, stair towers and truck dock doors closed.

7.2 MAINTENANCE. For efficient operation continual observation of the mechanical equipment itself, and the performance produced is necessary. A regular lubrication schedule should be in effect and daily logs of performance filed so that deviations are quickly apparent. Clean filters and proper fan drive alignment and tension mean full air delivery and accurate response to controls. Leaks in steam or water lines are wasteful and indicate lack of interest and concern for economy. Heat radiated from damaged or missing sections of covering is a loss and condensation in covering on cold surfaces removes insulating value. The condition of the building structure is also vital to economic operation. Caulking at window frames, sash seals, etc. should be kept in good condition. Any indication of drafts from outside in winter or condensation on ductwork above ceilings in summer indicate a serious opening or air passage in the building envelope. All of the heat transfer surfaces must be kept clean for efficient operation. This includes on the low temperature cycle the cooler and condenser tubes of the refrigeration machine, the air side of all cooling coils and tubes of any water to water inter-

changers in the circuits. On the heating side, all the boiler surfaces and tubes of the steam to water interchangers. Since total costs rise directly with operating hours, all start-up and shut-down schedules normally followed should be again carefully considered for any practical means to further limit actual operating times. If control is manual and erratic, investment in time clock cycled operation will pay for itself. Dual air duct and multizone systems are almost invariably setup controlled with too high temperatures on the hot deck. Both systems are subject to leakage of warm air at the unit and mixing box dampers, and this is an override which continually wastes energy. Most of these systems will operate adequately if the hot deck is no higher than the maintained room temperature. Review the operational controls on boilers and refrigeration machines. Where this equipment is in multiple units the operation and control system is very commonly designed to hold all units on down to relatively low load conditions. With some modification to controls, these units can be staged more efficiently so that operation of a single boiler or refrigeration machine can continue over a much longer period.

CHAPTER 8. DOMESTIC AND SANITARY WATER SYSTEMS

8.1 SERVICE WATER HEATING. In existing buildings, every effort should be made to conserve energy. Hot water for domestic and sanitary purposes should be generated and delivered in a manner conducive to saving heat energy. Wherever possible, existing sources of heat recovery should be used for water heating requirements.

8.1.1 Insulation. All unfired service hot water storage tanks and piping containing heated water should be insulated. Insulation which has been damaged or has deteriorated should be replaced. Insulation exposed to damage or weather should be shielded. Heat loss for above ground piping and storage tanks should be limited to 25 Btu/hr./ft.^{2}. Heat loss for underground piping and recirculating systems to 35 Btu/hr./ft.^{2}.

8.1.2 Temperature Control. Service water heating systems should be equipped with automatic temperature controls capable of adjustment to the lowest acceptable temperature setting for intended use (See Table). Water should not be heated and stored at a higher than utilization temperature. Where special functions, such as dishwashing, require higher temperature water, provide a local booster heater.

8.1.3 Pump Operation. Circulation systems should be so arranged that the circulating pump(s) can be conveniently turned off when the portion of or the building served by that pump is not in use.

8.1.4 Conservation of Energy. Showers used for other than safety reasons should be equipped with flow control devices to limit flow to 3 GPM. Control devices should also be considered for installation of lavatory faucets. Consideration should be given to recovery of heat from laundry waste water to pre-heat and/or heat service water. Rejected heat from refrigeration equipment, gas or diesel driven equipment can be recovered to heat service water. Where applicable, heat can be recovered from steam condensate.

8.1.5 Solar Heat. Use of solar heat to furnish domestic hot water requirements must be considered if economically justified.

TABLE 8-1

Hot Water Temperature Based on Utilization

Use	Temperature °F.
Lavatory	
Handwashing	105
Shaving	115
Showers and Tubs	110
Therapeutic Baths	110
Commercial and Institutional Dishwashing	
Wash	140
Sanitizing Rinse	180
Commercial and Institutional Laundry	180
Residential Dishwashing and Laundry	140
Surgical Scrubbing	110